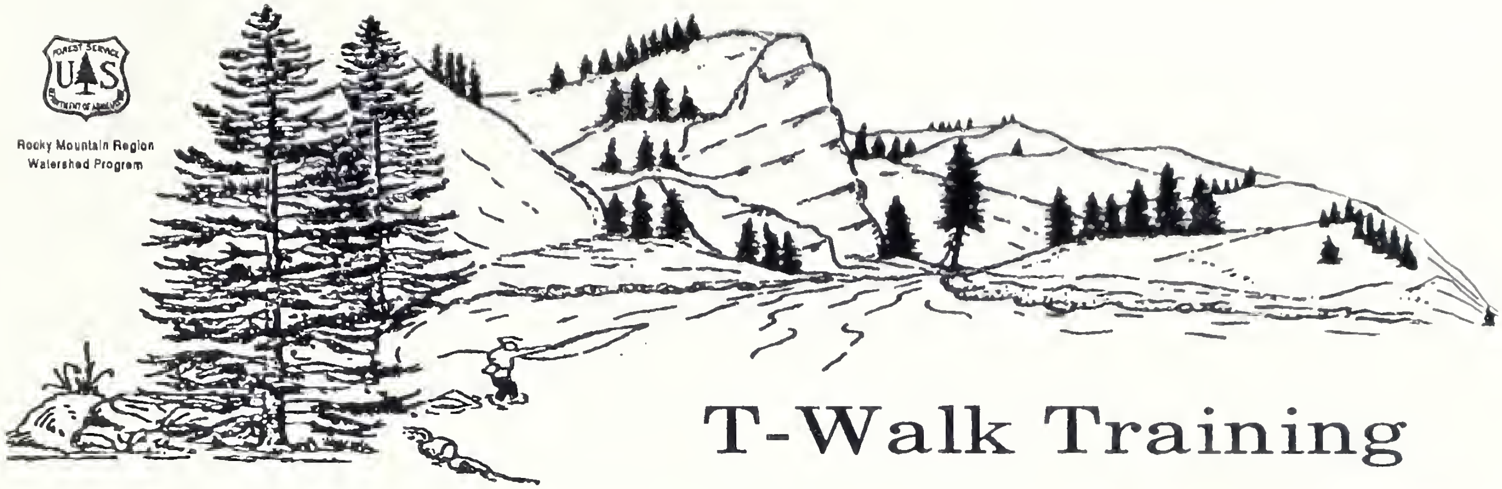
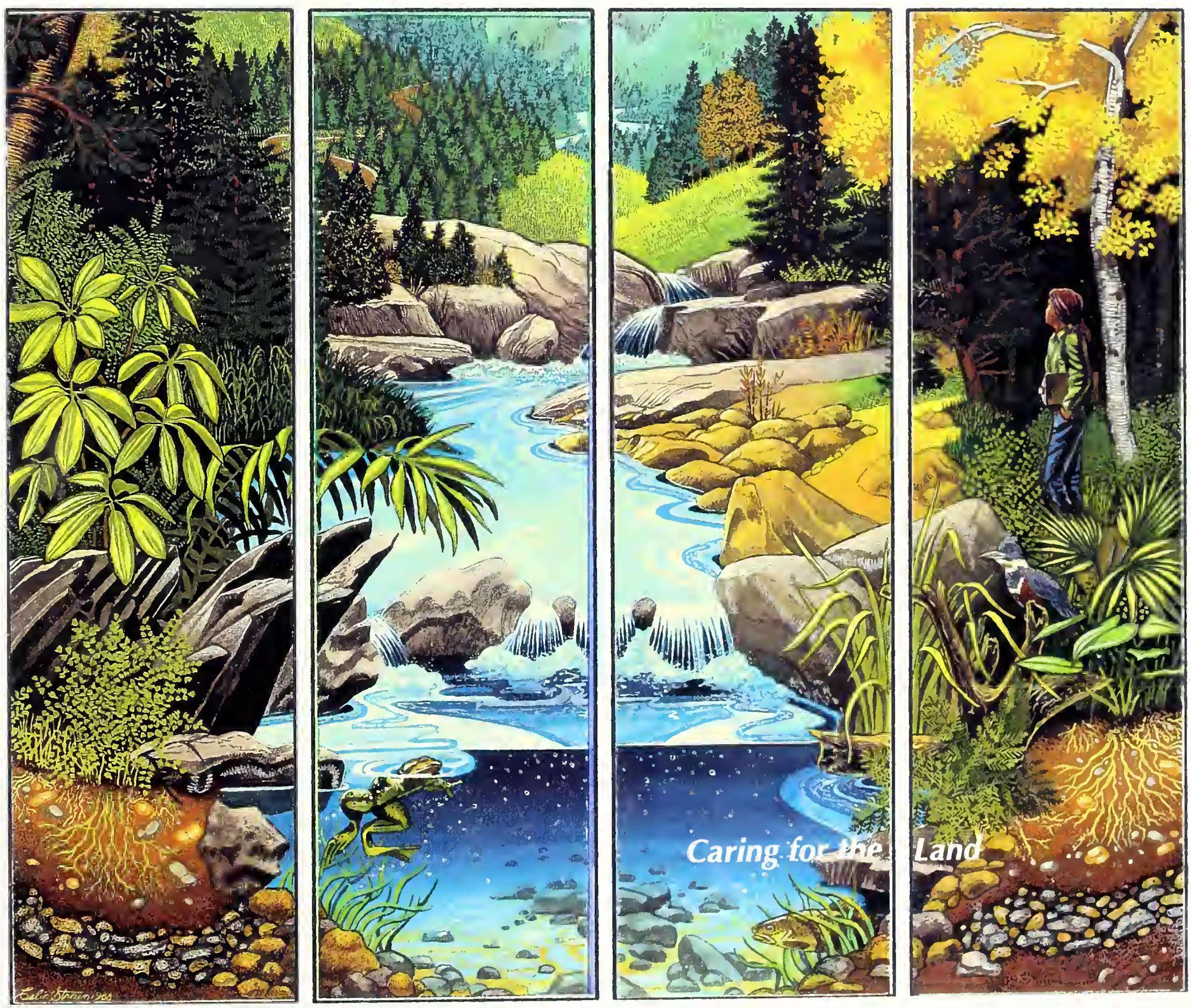


T-Walk Training



REGIONAL FORESTER
USDA, FOREST SERVICE
740 SIMMS STREET
BOX 25127
LAKEWOOD, COLORADO 80225

STREAM REACH REVIEW - Clean Water Act Monitoring

Watershed:
Name & # : ______________________________
Specific site char & Rx:

Local Directions:

Mer: Twns: Rng: Sec: QtrQtr:

ASSESSMENT of STREAM HEALTH

Stream Health Class		Existing	Expected 2 yr
R	Robust		
A	Adequate		
D	Diminished		
I	Impaired		
P	Precarious		
C	Catastrophic		

PROFILE OF NOTICEABLE OR EXPECTED CWA IMPACTS
(circle existing & arrow trends O-->)

R A D I P C = Sediment:

R A D I P C = Temperature:

R A D I P C = Oxygen levels reduced:

R A D I P C = Metals:

R A D I P C = Poisons:

R A D I P C = Equilibrium shifts:

R A D I P C = Dissolved salts/nutrients:

Synopsis & necessary response time to prevent futher damage:

EXPECTED CWA RESTORATION COSTS
(Fix diminishd, impaird, precarious, & catastrophic conditn)

Benefit Lag Time, years		Restoration Costs $1000	
No Plan	With Plan	Physical	Chem & Biolgcl

Reviewer & date passed to authority:

T-Walk 3/94

* THALWEG :
* Standard :
* T-Cleee : | Tarzwell :
* (@equil): | Subs Ratio :
* (existg): | TSR floor :

T-WALK STUDY
ID & date:

W'shed: Samples :
folio: & Photos:

CHANNEL MATERIALS - Size & Composition Summary
(mark d50, d84 size range)

Surface ! mud fine sand grvl cobl bldr bd lwd
(mm) ! depst <1> <16> <5"> <20"> rk <2'>

SubSurf ! mud fine sand gravl cobl bldr bd lwd
(mm) ! depst <1> <16> <5"> <20"> rk <2'>

Bankland structure (d84 of likely shear zone meterial)
Banks ! mud fine sand gravl cobl bldr bd lwd
(mm) ! <1> <16> <5"> <20"> rk <2'>

Strength ! y-cohsv-n lens no-root-gr/br/tr frac lwd

Geologic Rock Type - channel feature
Bslt Gran Lmst Mrin Mixt Rhyo Schs Sdst Shal Volc

CHANNEL PHYSICS

Watershed ! < 1 2 4 8 16 32 64 128 256 512 1024 >
Area sqm & !
Mn Elev, K ! <5 5 6 7 7.5 8 8.5 9 9.5 10 11 12 >

Channl Slp % ! < .05 .1 .5 1 1.5 2 3 4 10 > | CrvRad'
& Sinuosity ! step |
ratio. ! 1 1.2 1.4 1.6 1.8 2 2.2 2.4 > |

Width/depth ! < 2 4 6 8 10 12 14 16 20 25 30 > | BnkX/Y
Bnkfl wid' ! |
W/D ratios ! x 2 4 6 8 10 12 14 16 20 25 30 > |

Channl Depstn! <% 10 20 30 40 50 60 70 80 90 > | jams
Affctd len% ! |
Bar type(s) ! pnt side mid isle block dlta pedl |

Bed Stab mm ! < 4 8 16 32 64 128 256 512 > <-2'lwd->

Channl Banks ! Resid Glacl Mass-mvt Terrace Lake Jackstr
Mtrl Origin !
Bankld slp% ! < 2% 5 10 20 30 40 50 60 70 100 200 >

Downcut dp' ! < 1' 2 3 4 5 6 7 8 9 10 20 30 50 >

Stable len% ! < 5% 10 20 30 40 50 60 70 80 90 95 >

Instability ! bvr burn grz jam cast wall snag seep
triggers ! hiQ farm log orv pipe hcut ovrQ avln

T-CLASS (Thalweg stream & bankland regimes)

A= Agrs; B= Bal; C= Cum; F= Flat; H= Hydr; D= Dbrs; I= Incis
N= Narrwd; P= Period; S= Step; W= Wide; X= eXcavtd; Z= Zero
Mtrl: mud; fines; snd; grvl; cobl; bldr; brock; lwood; depst
Code bank depth('), origin: Res Glacl Mass Terr Lake Jack
& Bankland structure (m, f, s, g, c, b, r, l @ d84)

T-CLASS (x=Qbf wid) :
(xAr7Rr; 9BIc5Gg :

DIVERSITY SCREEN

Riffle insects ! 2My3 St C:bx-cone flt-rnd-spr scf net
larvae & nymphs !
(Sum of 10 cbls) ! 0 1 2 4 8 16 32 64 128 >128

Pools - % in reach ! 0% 1 5 15 33 50 67 85 95 99 | Tmp
! | C/F
max pool dep ' ! < 1' 1.5 2 2.5 3 3.5 4 5 > |
dep' & vel'/s ! <2d<1v <2d>1v >2d<1v >2d>1v |

Stream bank vegetn ! grs forb lo-shrub-hi conf decid
% for both banks ! 0% 1 5 15 33 50 67 85 95 99 >
root dep & density ! <QbSpars <QbDens >QbSpars >QbDens

Shores - % stabls & ! 0% 1 5 15 33 50 67 85 95 99 >
undercut/ovsrhang !
max shore depth' ! < .1 .2 .5 .8 1 1.2 1.5 2 2.5 >

Instream vegetation ! mld alg wood root | Lwd-pool #/r
% vege in reach ! |
#lwd pool/reach ! 0% 1 5 15 33 50 > | 0 1 2 4 8 16 >

Stains & precptates ! Wh R O Y G B I V Blk
bank or bottom ! none
color & extent ! sm-patch-lg seep 1- 2- 5- 10- gpm

STORM RUNOFF CONTROL
(40 acre evaluation cell; center on stream impact site)

I Site Protection:
Bare soil Pattrn : sm-patch-lg 25-ovrlp-50 rill gully
Ground cover % : < 10 20 30 40 50 60 70 80 90 >
LFH depth, ft : .01 .05 .1 .2 .3 .4 .5 .6 .8 >

II Concentration factors: |
Design roads: : < 1 2 3 4 5 6 7 8 > | Surfacs
Ditch slope % : |
Ditch len 100' : < 3 4 5 6 7 8 9 10 > |
Temp & prim road : 4 6 8 10 12 14 16 > | Road Ac
Surface slope %: |
Drain dst 100' : < 1 2 3 4 5 6 7 8 > |
Corridors & trls : 4 6 8 10 12 14 16 > | Rill dp'
Surface slope %: |
Drain dst 100' : < 1 2 3 4 5 6 7 8 > |
Connect Dstrb Ac : < 2 4 6 8 12 16 24 32 > | ConDA Ac
Surface slope %: at-risk |
Chan len 100' : 1 2 3 4 5 6 8 10 15 20 25 > |

III Dispersion factors:
Perm vege buffer : none
LFH depth, ft : .01 .05 .1 .2 .3 .4 .5 .6 .8 >
Slope % : 1 2 4 8 16 32 64 128 >
Ground cover % : < 10 20 30 40 50 60 70 80 90 >

Expedient traps : 0 .5 1 2 3 4 5 6 >6
Time left, yr : none
Kind of trap : Ebsn Ecut Efil Efur Epit Erow

Stream receptor : 1 5 10 15 33 50 67 85 90 95 >
Sedimnt yield% : none
Low flow condt : Per Bog Ovrflw Ditch Intmt Swale

THALWEG DEPTH (0.1' by tally)

Qbf to wtr: surface :	Tvel '/s	Max dp'	Min dp'
0.0 - <0.5	1.8 - <2.0	3.0 - <3.2	P o o
0.5 - <1.0	2.0 - <2.2	3.2 - <3.4	l
1.0 - <1.2	2.2 - <2.4	3.4 - <3.6	V e g
1.2 - <1.4	2.4 - <2.6	3.6 - <4.0	S h o
1.4 - <1.6	2.6 - <2.8	4.0 - <5.0	r
1.6 - <1.8	2.8 - <3.0	5.0 - over	L w d

TARZWELL SUBSTRATE RATIOS (by tally)

Sand dominatsd substrates !
Sands clean 1 !

Sands w/inorg muds 5 !
Grvl fn w/ infill !

Grvl md & crs /infill 12 !
Cobble; bldr w/ infill !

Sands w/muds & litter 13 !
Plants; moss w/ infill !

No sand infill; no plants !
Gravel fine 9 !

Gravel med or coarse 32 !
Cobble small !

Cobble lrg 50 !
Cobble & boulder !

Boulder sm & md 29 !

Boulder lrg & bedrock 15 !
Hardpan clay !

No sand infill; w/ plants !
Organic muds & muck 35 !
Coarse plant mtrl (CPOM) !

Rooted: <30% cover 67 !

Grvl fine w/moss 89 !

Grvl md & crs w/moss 111 !
Cobbls sm w/moss !

Cobble lrg w/moss 140 !
Bldr sm & md w/moss !

Rooted: >30% cvr & texture! 200 ! 300 ! 450 !
coarse 200; medium 300; ! ! ! !
fine or feathery 450 ! ! ! !

TARZWELL SUBSTRATE RATIO, TSR = *
Sum (ratios x % in reach) *

T R A C E monitoring follow-up

Evaluation Plan for: & When:

No follow-up | Trend | Reference | Advance | Effects

Compliance: Admin | Contract | Permit | WQS | Restore | Emergnc

Where:

Who:

How: (photos, samples, transects)

What: (parameters & frequency)

Why: (expected results, analyses, reports)

PEBBLE COUNT for:

Class	Size, mm	Tally	Tot/%Cum
Fines Si&Cl	<0.062		
Sand	0.062- 2		
Gravel v.fine	2- 4		
Gravel fine	4- 8 - 0.3"		
Gravel med	8- 16 - 0.6"		
Gravel coarse	16- 32 - 1.3"		
Gravel v.coars	32- 64 - 2.5"		
Cobble sm	64- 128 2.5- 5"		
Cobble lg	128-256 5"- 10"		
Bldr sm	256- 512 10"- 20"		
Bldr md	512-1024 20"- 40"		
Bldr lg	1024-2048 40"- 80"		
Bldr v.lg	2048-4096 80" 160"		
Bedrock	4096 - + 160" & >		

R E M E D I A L

Objective(s): (check-off objective & target date)

___ No action

___ Return to prior condition

___ Meet legal standards

___ Meet administrative standards

___ Betterment for economic reasons

Sponsors/Clientele:

Values to be protected:

Work items & amounts needed: (see abbrv list)

Clow Low flow channel structures for sediment control.
Cnew Channel construction new/enlarge.
Crem Channel debris/sediment removal.
Cstb Channel/shore bank material stability.
Ebsn Expedient sediment/debris basin.
Ecut Expedient in-stream trench or trough cut; no dam.
Efil Expedient filter/sorbent material fence.
Efur Expedient log & furrow erosion barriers.
Epit Expedient small sediment catch 'pit'.
Erow Expedient slash/brush windrow.
Rbar Water bar, road roll, & other cross drain repair.
Rcul Bridge & culvert stabilization.
Rdrn Road, trail, & corridor drainage ditch stabilization.
Rstb Road fill & bank stability.
Vbfr Permanent vegetation buffer for sediment control.
Vcvr Vegetative cover density for on-site erosion control.
Vexc Vegetation protection by livestock exclusion.

Funds and people needed:

Planner & :
Telephone :

STREAM REACH REVIEW - Clean Water Act Monitoring

Watershed:
Name & # :
Specific site char & Rx:

Local Directions:

Mer: Twns: Rng: Sec: QtrQtr:

ASSESSMENT of STREAM HEALTH

	Stream Health Class	Existing	Expected 2 yr
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I	Impaired		
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(circle existing & arrow trends O-->)

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R A D I P C = Metals:

R A D I P C = Poisons:

R A D I P C = Equilibrium shifts:

R A D I P C = Dissolved salts/nutrients:

Synopsis & necessary response time to prevent futher damage:

EXPECTED CWA RESTORATION COSTS
(Fix diminishd, impaird, precarious, & catastrophic conditn)

Benefit Lag Time, years		Restoration Costs $1000	
No Plan	With Plan	Physical	Chem & Biolgcl

Reviewer & date passed to authority:

T-Walk 3/94

R E M E D I A L

Objective(s): (check-off objective & target date)

___ No action \
___ Return to prior condition \
___ Meet legal standards \ ____________
___ Meet administrative standards /
___ Betterment for economic reasons /

Sponsors/Clientele:

Values to be protected:

Work items & amounts needed: (see abbrv list)

Clow	Low flow channel structures for sediment control.
Cnew	Channel construction new/enlarge.
Crem	Channel debris/sediment removal.
Cstb	Channel/shore bank material stability.
Ebsn	Expedient sediment/debris basin.
Ecut	Expedient in-stream trench or trough cut; no dam.
Efil	Expedient filter/sorbent material fence.
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Epit	Expedient small sediment catch 'pit'.
Erow	Expedient slash/brush windrow.
Rbar	Water bar, road roll, & other cross drain repair.
Rcul	Bridge & culvert stabilization.
Rdrn	Road, trail, & corridor drainage ditch stabilization.
Rstb	Road fill & bank stability.
Vbfr	Permanent vegetation buffer for sediment control.
Vcvr	Vegetative cover density for on-site erosion control.
Vexc	Vegetation protection by livestock exclusion.

Funds and people needed:

Planner & :
Telephone :

REGIONAL FORESTER
USDA, FOREST SERVICE
740 SIMMS STREET
BOX 25127
LAKEWOOD, COLORADO 80225

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

WATER RESOURCES ANALYSES

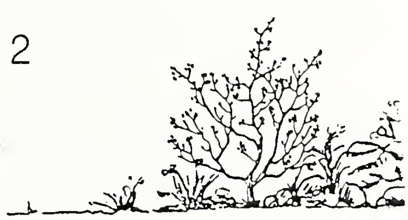
T-Walk

Water Quality Monitoring
Field Manual & Tables

Assessment Review

End Date 3/95

REGION 2



WATER QUALITY GOAL

Protect the physical, chemical, and biological integrity of the nation's water. [Clean Water Acts 1948, '72, '77, '87]

Striving towards and maintaining the pristine state minimizes the burden to society in maintaining a healthy environment and the stable biosphere that is essential to human well-being. [3742 USCC&AN 1972]

Maintenance of such integrity requires that changes in the environment resulting in a physical, chemical or biological change in a pristine water body be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original. [3742 USCC&AN 1972]

Antidegradation requires that existing uses actually attained in the water body on or after November 28, 1975, shall be maintained and fully protected; the protection is dependent on physical as well as chemical factors and includes substrate suitability, cover, flow, depth, pools, riffles, and the like. [40 CFR 131.12 & .10g].

"Aquatic environment" and "aquatic ecosystem" means "waters of the U.S." that serve as habitat for interrelated and interacting communities and populations of plants and animals. This includes waters and their impoundments such as lakes, rivers, streams, intermittent streams, mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds; or their tributaries. (40 CFR 230.3(c & s)).

SELECTED WATER QUALITY CASE LAW

The guiding star is the intent of Congress to improve and preserve the quality of the Nation's waters and all issues must be viewed in light of such intent. 612 F.2d 1231; 540 F.2d 1023; 97 S.Ct 1340; 97 S.Ct 1672.

CWA is broad and remedial, and is intended to restore and maintain natural chemical, physical, and biological integrity. 438 F.Supp 945.

Agents may be subject to liability for wrongful acts either in tort or in contract [728 F.2d 1006]. An agent's personal liability is not affected by the fact that it acted on behalf of its principal [525 F.Supp 1104].

** Corky Ohlander. Hydrology. Phone: 303 275-5097
USDA Forest Service, P.O.Box 25127, Lakewood CO 80225
April 1994

MANDATORY BEST MANAGEMENT PRACTICES

CWA S404(f)(1)(E) Exemption requires construction and maintenance of permanent and temporary roads and skid trails in accordance with BMPs to assure that flow & circulation patterns and chemical & biological characteristics of "waters of the U.S." are not impaired, that the reach is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. Mandatory S208* & COE [33 CFR 323.4(a)(6)] BMPs are paraphrased as follows:

1 limit road & trail system to the minimum feasible number, width, and total length consistent with the specific operations, topography, and climate;
2 except at crossings, all roads and trails* shall be located sufficiently far from streams or other water bodies to minimize discharges;
3 crossings shall not restrict the passage of expected floods flows;
4 fills shall be stabilized during & after construction to prevent erosion;
5 minimize equipment disturbance in "waters" outside construction zone;
6 minimize vegetative disturbance in "waters" during and after construction;
7 road crossings shall not disrupt the movement of resident aquatic species;
8 take borrow material from upland sources whenever feasible;
9 the discharge shall not take, or jeopardize the continued existence of, a T&E species, or adversely modify or destroy critical habitat;
10 avoid discharges into migratory waterfowl habitat, spawning areas, and special aquatic sites [40 CFR 230.10(a)(3)]; special aquatic sites include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, and riffle and pool complexes. [40 CFR 230.3(q-1)].
11 discharge shall avoid areas in or near public water supply intake;
12 discharge shall avoid areas of concentrated shell fish production;
13 discharge shall avoid National Wild and Scenic River System reaches;
14 discharge material will be free from toxic pollutants in toxic amounts;
15 all temporary fills will be removed and restored to original elevation.

STREAM REACH REVIEW - Clean Water Act Monitoring

Thalweg Walk (T-Walk) Advance Warning System Procedures
(Field manual - effective use requires prior training.)

Perspective

Diversity, productivity, and stability are compared to long term natural conditions. Desired health is reflected by the greatest standing crop and greatest niche partitioning. For advance warning purposes, the aquatic macroinvertebrate community is the best place to look for early signs of stress; many species are sensitive to pollution and respond quickly to it; bottom fauna tend to have complex life cycles and die off if conditions are outside tolerance limits; and many species have an attached or sessile form and cannot migrate to avoid the stress.

Recovery depends on type of impact. Non-selective physical impacts tend to leave adequate gene pools and revitalization of health will proceed rapidly upon removal of the stress condition. Recovery from selective chemical impacts requires an improved physiochemical environment and, perhaps, rebuilding an adequate gene pool.

Focus - To fix existing & potential problems while they are still small. Restoration costs run about 20 times the ordinary prevention costs.

Purpose: Advance Warning of existing or potential impacts on stream health. Notification & documentation of CWA related issues:

1. summary of land use & BMP impacts on CWA water quality;
2. summary of current and future (2 year) stream health;
3. expected restoration costs to recover Robust stream health;
4. a quick fix remedial action plan and follow up monitoring plan;
5. documentation of field observations.

Equipmt: Waders, 5x hand level, T-Stick, survey rod, 5-10x hand lens, 100' measure, insect repellent, M+calc, % clinometer, map, pins, C/F therm, trowel, snooper, cord & line level. Optnl: Camera, mm ruler.

<u>Scale for Impact Analysis</u> - Ideally, center a 40 acre evaluation cell on the major intersection of the management activity and the stream. This divides into two 1/8 mile (660') stream reaches and allows the above reach to be compared to the below reach for an estimate of impact. In field use, reaches may be longer or shorter and located to get the best information.

This manual follows the normal steps used for site analysis: begin with road & upland conditions, track the effects into the stream, & estimate current & future stream health, restoration, and follow-up monitoring.

Stream Health - The purpose of T-Walk is to determine Stream Health for each stream based on its own capability defined in terms of diversity, stability, & productivity. The Stream Health evaluation strives to answer three questions:

What is it now? What should it be? What has to be fixed?

Stream Health Class -

Stream Health Class is a combination of ecosystem stability and diversity (as defined by the aquatic life health class) and production (as defined by the ecological carrying capacity ratio). It is defined by the lowest of the two scales (i.e. 'Robust' aquatic life and 'Impaired' production = 'Impaired' Stream Health). The scales are not averaged; the definition of limiting factors is valuable for understanding restoration factors and preventing further damage.

Aquatic Life Health Classes definitions (EPA 1983):

Class	Attributes
Robust	Having or exhibiting strength or vigorous health; flourishing condition (Webster). Comparable to the best situations unaltered by man; all regionally expected species for the habitat and water body size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Adequate	Lawfully and reasonably sufficient for a specific requirement (Webstr). Fish and macroinvertebrate species richness somewhat less than the best expected situation, especially due to loss of most intolerant forms; some fish species with sub- optimal size distributions or abundances; trophic structure shows some sign of stress.
Diminished	Made smaller; lessened; reduced; -as in size, degree, or importance (Webster). Fewer intolerant forms of fish and macroinvertebrates are present. Trophic structure of the fish community is more skewed toward an increasing frequency of omnivores; older age classes of top carnivores may be rare.
Impaired	Made worse; diminishing in some material way (Webster). Fish community is dominated by omnivores; pollution tolerant forms & habitat generalists; growth rates and condition factors commonly depressed; few top carnivores; hybrids and diseased individuals may be present. Pollution tolerant macroinvertebrates are often abundant.
Precarious	Lack of security or stability that threatens with danger (Webster). Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, physical damage, and other anomalies regular. Only tolerant forms of macroinvertebrates are present.
Catastrophic	Complete failure; calamity (Webster). No fish, very tolerant macroinvertebrates, or no aquatic life. Ecological upset and collapse; retrogression.

Stream Health Class

(Combination of aquatic life health and carrying capacity ratios)

Aquatic Life Health Class	Ecological Carrying Capacity Ratios 1.0-0.9	<.9-0.7	<.9-0.7	<.7-0.5	<.5-0.3	<.3
Robust	ROBUST	ADEQUATE*	Diminish	Impaired	Precari	Catastr
Adequate*	ADEQUATE*	------->	Diminish	Impaired	Precari	Catastr
Diminished	Diminished	---------------->		Impaired	Precari	Catastr
Impaired	Impaired	-------------------------->			Precari	Catastr
Precarious	Precarious	-->				Catastr
Catastrophic	Catastrophic	-->				

* Adequate only applies to legally impacted stream reaches.

Storm Runoff Control -

I Site Protection - excluding roads or trails, how well is the site protected? Make a contour transect across the more exposed or beat up sites and report on:

Bare soil patterns - show worst water concentration patterns as small & large patches that are not connected, overlap, and rills or gullies.

Ground cover % - total area % of LFH plus live ground cover.

LFH layer depth, ft - long term depth of litter + fermented + humus.

II Concentration factors -

How are pollutants brought together and concentrated? In particular, roads, trails, and any corridor that modifies natural drainage changes timing, volume, and peak flow delivery to streams; sediment is often carried with it. For **Design roads, Temporary & primitive roads, Corridors & trails, & Connected Disturbed Area Acres**, record slope %, distance between cross drain features, and disturbed area channel length. Summarize **Surface, Road Acres, Rill depth** (0.1' depth for the most eroded surface), **& Connected Disturbed Area Acres.** Mark "at-risk" if (CDA^0.5)*Slp%/Wid' > 3.6. (Slp% & Wid' is at peak flow wetted perimeter).

III Dispersion factors -

Where do pollutants and sediments end up? For example, stream impacts from excess sand remain until they are flushed into deep water or dredged out. Objective: keep pollutants out of water to start with.

Permanent vegetative buffer - least-cost long term sediment control:

LFH depth, ft - buffer long term litter + fermented + humus depth.

Slope % - average slope of area used as buffer.

Ground cover % - total area % of LFH plus live ground cover.

Expedient traps - temporary measures; but they must last long enough to prevent overwhelming the natural buffer capacity and to meet revegetation standards on exposed sites.

Time left, yr - estimate current fill rate & remaining life.

Kind of trap - common temporary sediment control treatments

- Ebsn Expedient sediment/debris basin.
- Ecut Expedient in-channel trench or trough cut; no dam.
- Efil Expedient filter/sorbent material fence.
- Efur Expedient log & furrow sediment control.
- Epit Expedient small sediment catch 'pit'.
- Erow Expedient slash/brush windrow.

Stream receptor - Sediment yields are tough to estimate. Start at the worst sediment source, track the eroded sand material through the buffer and temporary traps, then estimate what % made it to the stream. Estimate **Sediment yield %** as that part deposited into the drainage feature. Since the receiving stream condition is also important, record what it is: perennial or intermittent, bog or wetland, overflow, ditch, or a swale.

If roads are a major source, **Sediment yield %** is the % of culverts & drains that lack an adequate buffer or flows direct into the stream network. If the **Vbfr** equation calculates a buffer length greater than the field condition, the buffer is too short. The **Vbfr** equation is based on data from paved, gravel, and dirt roads; it is applicable to most watershed development activities.

Vbfr= [10 + 10xRms + 100xGdp]/[Vcvr] where:

Vbfr = vegetated buffer needed to trap road & ditch erosion, ft.
Rms = (Road cross drain distance/1000) times (Road slope%)
Gdp = Ditch cutting or gullying in the ditch bottom; 0.1 ft.
Vcvr = Buffer Type (SEDFLOW) or = (plant + crs wood & herb litter, dec%).

Buffer Type & Condition			Vcvr Expect'd	& Range
S	Swale	undisturbed; no rills	0.4	0.3 - 0.5
E	Eroded	old rills common	0.2	0.1 - 0.3
D	Drops	holes, depressions	1.0	1.0
F	Fans	sidehill & ridge, no rills	(plant + crs wood & herb, dec%)	
L	LWD	windrows, slash, natrl falls	1.0	1.0
O	Open	trails, paths; not connected	0.4	0.3 - 0.7
W	Wander	cobbles, hummocks; no rills	1.0	1.0

```
==============================================================
                      STORM RUNOFF CONTROL
   (40 acre evaluation cell; center on stream impact site)
--------------------------------------------------------------
I  Site Protection:
   Bare soil Pattrn : sm-patch-lg  25-ovrlp-50  rill  gully
                    :
   Ground cover %   : < 10  20  30  40  50  60  70  80  90 >
                    :
   LFH depth, ft    : .01  .05  .1  .2  .3  .4  .5  .6  .8 >
--------------------------------------------------------------
II  Concentration factors:                      |
   Design roads:    : <  1  2  3  4  5  6  7  8  >  | Surface
     Ditch slope %  :                               |
     Ditch len 100' : < 3  4  5  6  7  8  9  10  >  |
------------------------------------------------|---------
   Temp & prim road :  4  6  8  10  12  14  16  >   | Road Ac
     Surface slope %:                               |
     Drain dst 100' : < 1  2  3  4  5  6  7  8  >   |
------------------------------------------------|---------
   Corridors & trls :  4  6  8  10  12  14  16  >   | Rill dp'
     Surface slope %:                               |
     Drain dst 100' : < 1  2  3  4  5  6  7  8  >   |
------------------------------------------------|---------
   Connect Dstrb Ac : < 2  4  6  8 12 16 24 32  >   | ConDA Ac
     Surface slope %:                    at-risk    |
     Chan len  100' : 1 2 3 4 5 6 8 10 15 20 25 >   |
--------------------------------------------------------------
III Dispersion factors:
   Perm vege buffer :                                   none
     LFH depth, ft  : .01  .05  .1  .2  .3  .4  .5  .6  .8 >
                    :
     Slope %        :  1   2   4   8   16   32   64   128  >
                    :
     Ground cover % : < 10  20  30  40  50  60  70  80  90 >
 ------------------------------------------------------------
   Expedient traps  :   0   .5   1   2   3   4   5   6  >6
     Time left, yr  :                                   none
     Kind of trap   :   Ebsn  Ecut  Efil  Efur  Epit  Erow
--------------------------------------------------------------
   Stream receptor  : 1  5  10  15  33  50  67  85  90  95 >
     Sedimnt yield% :                                   none
     Low flow condt :  Per  Bog  Ovrflw  Ditch  Intmt  Swale
==============================================================
```

Thalweg Depth (by tally)

This is the heart of **T-Walk**. The purpose is to characterize the thalweg depth and evaluate substrate conditions that influence fish food production.

Location is important. **T-Walk** must be done close enough to address stream impact, but not so close that sacrifice (wipe-out) areas are included. For example, leave 200′ below construction sites before starting a T-Walk reach.

Work along the reach at equally spaced distances. Surveys with 30, 50, or 100 points are common. Select the number of points that will pick up the variety in pool depths. For shallow streams (<2′) with regular features, 30 points (22′±) provide minimum statistical control. For deeper streams or those with pool-riffle or step-pool sequences, 50 points (13′±) are needed to provide minimum statistical control (2/3 chance) and 100 points (7′±) provide substantially better statistical control (9/10 chance).

Thalweg Depths - low water surface; tally depth by category.

Qbf to water surface **0.1′** - provides year to year stage reference.

If Qbf is not used, note precisely what was & location.

Thalweg velocity ′/s - if hiQ use 0.8x float vel or 8*sqrt(vel head).

Max & Min depth 0.1 ft - record maximum & minimum of all points.

Pool, Veg, Shore, & Jam - dot tally for use in the Diversity Screen.

Depth Categories - at each point measure the thalweg (deepest) and tally the appropriate depth category. At end, convert tally into <=% category exceedence values and plot using max & mins as graph limits.

Tarzwell Substrate Ratio (by tally)

Sedimentation of coarse substrates by sand produces significant detrimental effects on salmonid resources by affecting spawning areas and by reducing primary and secondary production. **Tarzwell Substrate Ratio** is a dimensionless measure of macroinvertebrates produced on different substrates indexed to sand as the least productive. The tally uses 3 groups: sand dominated substrates, rock dominated substrates without excess sand, and substrates influenced by vegetation or organic matter. Excess sand shows as waves behind larger rock, as dunes or ripples, as embedded gravel, or as buried plants. Sand infill begins when >10% of larger rock surface or perimeter is obscured.

Tarzwell Substrate Ratio - Near the depth tally spot, visually match the substrate to the TSR categories. If you can't see, try a snooper. Individual rocks sometimes indicates embedded condition by color change or animals just only along the fringe. When tally is complete, convert dot tally into % for each category, multiply category TSR by its %, and total. The total is an average Tarzwell Substrate Ratio for the reach.

THALWEG DEPTH (0.1' by tally)

Qbf to wtr: surfacs :	Tvel '/s	Max dp'	Min dp'	
0.0 - <0.5	1.8 - <2.0	3.0 - <3.2		P o o l______
0.5 - <1.0	2.0 - <2.2	3.2 - <3.4		
1.0 - <1.2	2.2 - <2.4	3.4 - <3.6		V e g______
1.2 - <1.4	2.4 - <2.6	3.6 - <4.0		S h o r______
1.4 - <1.6	2.6 - <2.8	4.0 - <5.0		
1.6 - <1.8	2.8 - <3.0	5.0 - over		J a m

TARZWELL SUBSTRATE RATIOS (by tally)

Sand dominated substrates		
Sands clean	1	
Sands w/inorg muds Grvl fn w/ infill	5	
Grvl md & crs /infill Cobble; bldr w/ infill	12	
Sands w/muds & litter Plants; moss w/ infill	13	
No sand infill; no plants		
Gravel fine	9	
Gravel med or coarse Cobble small	32	
Cobble lrg Cobble & boulder	50	
Boulder sm & md	29	
Boulder lrg & bedrock Hardpan clay	15	
No sand infill; w/ plants		
Organic muds & muck Coarse plant mtrl (CPOM)	35	
Rooted: <30% cover	67	
Grvl fine w/moss	89	
Grvl md & crs w/moss Cobble sm w/moss	111	
Cobble lrg w/moss Bldr sm & md w/moss	140	
Rooted: >30% cvr & texture coarse 200; medium 300; fine or feathery 450		200 ! 300 ! 450 !

TARZWELL SUBSTRATE RATIO, TSR = * *
Sum (ratios x % in reach) * *

Channel Materials - mark d50 & d84 of surface materials (i.e. Pebble Count); note bimodal distributions. Be specific but without forcing the data. Remove the top layer to check subsurface materials; note any unusual layers or size combinations. Look for d84 for the bankland rock composition; slope stability depends on the structural interlock provided by larger sizes. Find high flow stage (Qbf); note d84 of weakest layer or plane between different sedimentary beds. Bank strength is an integrated feature: note cohesive matrix (yes/no); non-cohesive or slip lens; rooting at Qbf (if yes, mark grass, shrub, or trees); pipe or side fracture; and large woody debris (lwd = 4" >).

Mark the geologic rock types that dominate in the stream feature; be aware of unusual combinations like shale overlain by sandstone cobbles.

Form choices: basalt, granite, limestone, marine shales (high salt), mixtures like outwash, rhyolite, schist, sandstone, shales, volcanics.

```
============================================================
         CHANNEL MATERIALS - Size & Composition Summary
                   (mark d50, d84 size range)
------------------------------------------------------------
 Surface  ! mud  fine  sand   grvl   cobl   bldr    bd   lwd
    (mm)  !   depst    <1>    <16>   <5">   <20">   rk   <2'>
          !
 SubSurf  ! mud  fine  sand   gravl  cobl   bldr    bd   lwd
    (mm)  !   depst    <1>    <16>   <5">   <20">   rk   <2'>
------------------------------------------------------------
   Bankland structure (d84 of likely shear zone material)
 Banks    ! mud  fine  sand   gravl  cobl   bldr    bd   lwd
    (mm)  !            <1>    <16>   <5">   <20">   rk   <2'>
          !
 Strength !  y-cohsv-n   lens  no-root-gr/br/tr   frac   lwd
------------------------------------------------------------
            Geologic Rock Type - channel feature
 Bslt  Gran  Lmst  Mrin  Mixt  Rhyo  Schs  Sdst  Shal  Volc
============================================================
```

PEBBLE COUNT for:

Class	Size, mm	!	Tally	Tot/%Cum
Fines Si&Cl	<0.062	!		
Sand	0.062- 2	!		
Gravel v.fine	2- 4	!		
Gravel fine	4- 8 - 0.3"	!		
Gravel med	8- 16 - 0.6"	!		
Gravel coarse	16- 32 - 1.3"	!		
Gravel v.coars	32- 64 - 2.5"	!		
Cobble sm	64- 128 2.5- 5"	!		
Cobble lg	128-256 5"- 10"	!		
Bldr sm	256- 512 10"- 20"	!		
Bldr md	512-1024 20"- 40"	!		
Bldr lg	1024-2048 40"- 80"	!		
Bldr v.lg	2048-4096 80" 160"	!		
Bedrock	4096 - + 160" & >	!		

Channel Physics - stream health is sensitive to stream energy and channel geometry changes. Obtain **Watershed area & mean elevation** from the map. Use a mounted 5x hand level & survey rod (or cord line & level) to measure **Channel Slope** (water surface); do it carefully. Note if this is a **step-pool** system.

Sinuosity - ratio; chnl len/valley length. Outer bank curve radius '.

Bankfull Width & Depths - take time to find good bankfull indicators. From width and average depth (from Qbf line); calculate W/D ratio.

Mark **Bank X/Y** (cotangent) ratio; for the same materials, steep bank sections are more erosive than gentle bank slopes.

Channel Deposition - % reach with point bar, side bar, mid-channel bar, islands, blocks & cutoffs, tributary delta bars, or pedestals (bank remnant). Count jams that block more than 1/4 Qbf stage. Select features that create **Bed Stability** and record rock size (mm) & major elements of stable lwd.

Banklands - Mark the bank **material origin** - residual, glacial, mass movement, terrace or lake deposits, or a jackstraw mix of large woody material and soils as might be found in an area of beaver dams or land slides.

Bankland Slope - % slope of non-bedrock mtrls above the outer bank curve.

Downcut depths (ft) - measure from channel bottom to 1st bench where flows will no longer be confined. If there is a 2nd bench, flag & note height from its toe to top. For **Stable length** (% reach length), check the straight and outside curves for bankfull indicators; what % are aged and well marked, what % are raw site? In evaluating vegetation -- count only durable and/or fibrous root systems and large structural features. Look carefully; banks with new instream features or newly grassed conditions may still be unstable.

Instability triggers - Beaver; high flows (& dam operation & floods); burns; farming; grazing; logging; jams; mine & road side cast; off-road vehicles; pipe (easily sugared, piped, sand lens); head wall; head cut; snagging; overbank flows; seeps & slumps; debris avalanche.

```
============================================================
                         CHANNEL PHYSICS
------------------------------------------------------------
Watershed     ! < 1  2  4  8  16  32  64  128  256  512 1024 >
 Area sqm &   !
 Mn Elev, K   ! <5  5  6  7  7.5  8  8.5  9  9.5  10  11  12 >
------------------------------------------------------------
Channl Slp %  ! < .05  .1  .5  1  1.5  2  3  4  10 > | CrvRad'
 & Sinuosity  !                                step |
    ratio.    ! 1  1.2  1.4  1.6  1.8  2  2.2  2.4 > |
------------------------------------------------------------
Width/depth   ! < 2  4  6  8  10 12 14 16 20 25 30 > | BnkX/Y
 Bnkfl wid'   !                                       |
 W/D ratios   ! x 2  4  6  8  10 12 14 16 20 25 30 > |
------------------------------------------------------------
Channl Depstn! <% 10  20  30  40  50  60  70  80  90 > | jams
 Affctd len%  !                                         |
 Bar type(s)  ! pnt  side  mid  isle  block  dlta  pedl |
              !                                         ------
 Bed Stab mm  ! < 4  8  16  32  64  128  256  512 >  <-2'lwd->
------------------------------------------------------------
Channl Banks  ! Resid  Glacl  Mass-mvt  Terrace  Lake  Jackstr
 Mtrl Origin  !
 Bankld slp%  ! < 2%  5  10  20  30  40  50  60  70  100 200 >
              !
 Downcut dp'  ! < 1'  2  3  4  5  6  7  8  9  10  20  30  50 >
              !
 Stable len%  ! < 5%  10  20  30  40  50  60  70  80  90  95 >
              !
 Instability  !  bvr  burn  grz  jam  cast  wall  snag  seep
  triggers    !  hiQ  farm  log  orv  pipe  hcut  ovrQ  avln
------------------------------------------------------------
```

T-Class (Thalweg stream and bankland regimes) - includes physical process factors important for maintenance and restoration of stream systems. **T-Class** is an open ended classification designed to incorporate existing & potential typic model interpretations. Make **T-Class** specific; code unusual subsurface materials, bimodal distributions, and equilibrium modifiers.

```
============================================================
        T-CLASS (Thalweg stream & bankland regimes)
------------------------------------------------------------
 A= Agrs; B= Bal; C= Cum; F= Flat; H= Hydr; D= Dbrs; I= Incis
 N= Narrwd; P= Period; S= Step; W= Wide; X= eXcavtd; Z= Zero
 Mtrl: mud; fines; snd; grvl; cobl; bldr; brock; lwood; depst
Code bank depth('), origin: Res Glacl Mass Terr Lake Jack
    & Bankland structure (m, f, s, g, c, b, r, l  @ d84)
------------------------------------------------------------
  T-CLASS (x=Qbf wid) :
   ( xAr7Rr; 9BIc5Gg  :
============================================================
```

T-CLASS - combines stream and bankland regimes:

1 Code stream width (x') and Geomorphic stream equilibrium character:

- A type — Aggressive; stream power is sufficient to keep excess sand sediment from accumulating even during low flow seasons; 90% of water year has 'hungry water'. Depositional features rare. 4- <10% slope.
- B type — Balanced; stream power is sufficient to move excess sand sediment load and flush out pools during seasonal high water. Sediment accumulates during low flow conditions. Depositional features common; point bars usually truncated. 1.5- <4% slope.
- C type — Cumulative; stream lacks power to move excess sand sediment load; pools and riffles common; well developed sinuosity. Depositional features abundant; point bars well developed. 0.5- <1.5% slope.
- F type — Flat; sand and fine materials common; bedforms if present are sediment transport related. Deposition forms abundant. <0.5% slope.
- H type — Hydraulic; stream power is sufficient to create hydraulic transport of coarse fragment bed materials (d50 = 0.25 - 1.5'). 10% &> slope.

Modifiers to define equilibrium shifts (briefed):

- D — Debris - channel braiding; surface water loss. Ex: xCD
- I — Incised - accelerated down cutting; rejuvenation. Ex: xBI
- N — Narrowed - channel width reduced. Ex: xCN
- P — Periodic - intermittent, ephemeral; natural or human. Ex: xBP.
- S — Step - step-pool systems; rock or lrg wood debris control. Ex: xBS.
- W — Widened - channel width expanded. Ex: xBW
- X — eXcavated - re-routed, channelized, straightened. Ex: xCX.
- Z — Zero - seasonal 0 flow from diversn & dam operations. Ex: xAZ.

2 Channel materials - alpha codes for surface (from d84) and subsurface:
r = bedrock, b = boulders, c = cobbles, g = gravel, s = sands,
f = fines (silt & clay), m = mud & muck, l = large woody debris
d = deposits of recent, fresh, soft or unconsolidated materials.

- Surface code reflects an expected log-normal size distribution; e.g. code 'c' d15 - d84 range is from sand to cobbles. Subsurface codes are added when there is a misfit between the surface and the subsurface. For example, sandstone cobble on 3% shale bed is coded 'xBcf'.

3 Bankland regime - code bank height directly followed by alpha code for the deposition process and d84 rock size of likely shear zone. For multiple banks code each sequence. Code depositional processes as:

- G type - Glacial; glacial processes; moraines, till, drift deposits.
- M type - Mass movement; dominated by earthflows, soil creep, slides.
- R type - Residual; dominated by colluvial processes and bedrock materials.
- T type - Terrace; fluvial processes; alluvial & fan deposits.
- L type - Lake; deposits exposed by lowering water or by land lift.
- J type - Jackstraw; flow patterns modified by surface & buried wood debris.

Examples: (x=Qbf wid') 20Bc2Ts6Tg; 3Ab4R; 5Cg24Ms; 9BWgd1Gg; 15BSg2Jg.

Thalweg Standard (T-Std) - defines conditions of Robust health possible for the study reach and provides the necessary CWA goal comparison. It is essential to match the **Thalweg Standard** to project conditions for valid comparisons. If Robust stream health conditions exist, then use 'before/after' or 'above/below' comparisons to determine Stream Health. Record the name, **T-Class** at equilibrium, and **Tarzwell Substrate Ratio** for the Thalweg Standard. If **T-Class** is different, then select an off-site Thalweg Standard with the same T-Class.

If Robust conditions are absent, then antidegradation is also at issue. Record the existing **T-Class** and **Tarzwell Substrate Ratio** that defines the antidegradation limits.

T-WALK study identification & date - make it clear; name the **Watershed folio** used to store such data and cross file any **Samples & photos.** Do it well; to quickly find data & use for later analyses makes you look ready for promotion.

```
************************************************************
* THALWEG  :                                               *
* Standard :_______________________________________________*
*  T-Class :                 | Tarzwell    :               *
*  (@equil):                 | Subs Ratio  :               *
*       ---:-----------------|------------:----------------*
*  (existg):                 |  TSR floor  :               *
*          :                 |             :               *
************************************************************
T-WALK STUDY
  ID & date:
------------------------------------------------------------
  W'shed:                       Samples :
   folio:                       & Photos:
============================================================
```

Diversity Screen - (late season (low flow) and fair weather conditions).

Riffle Insects - pick up 10 fist size rocks (or equivalent) from riffle areas. Study each rock with a hand lens and record the total of all nymphs & larvae for the 10 rocks. Record presence of mayfly and stonefly nymphs, and caddisfly larvae & cases. Mayflies have lateral abdominal gills (back end looks fuzzy w/ 2 or 3 tails) & stoneflies do not (2 tails clean outline). Mark all characteristic case shape & material: organic boxlike or cones; sand grain flat, round, or spiral; loose "scaffold" of leaves, twigs, or pebbles; and webs, socks, or trumpet-like nets.

Pools - record flat & pool water %, maximum depth, & temperature (optional). For 2′ depth and 1′/s velocity; mark all the categories that apply.

Stream bank vegetation - % total for both banks and what kind: grass, forbs, low shrub (<2′), hi shrub, conifer, or deciduous trees. Roots may be shallow (<Qbf) or deep (>Qbf) with either a sparse or dense root network.

Shores - % total for both banks w/ stable bank undercut or vegetation overhang. Record maximum shore depth (at water surface), 0.1′.

Instream vegetation - % of reach w/ brown or grey fungus scummy mold, filamentous or matted algae, wet wood (branches & >), and rooted water plants. Count Lwd induced pools or flat water habitats in reach, #/660′ reach.

Stains & precipitates - natural or man made mineral/organics deposits (patches, seeps, or gal/minute flow) w/ white, red, orange, yellow, green, blue, indigo, violet, black colors. Red & yellow will be most obvious; but look carefully - some very toxic materials are not obvious.

DIVERSITY SCREEN

Riffle insects larvae & nymphs (Sum of 10 cbls)	2My3 St C:bx-cone flt-rnd-spr scf net 0 1 2 4 8 16 32 64 128 >128	
Pools - % in reach max pool dep ′ dep′ & vel′/s	0% 1 5 15 33 50 67 85 95 99 < 1′ 1.5 2 2.5 3 3.5 4 5 > <2d<1v <2d>1v >2d<1v >2d>1v	Tmp C/F
Stream bank vegetn % for both banks root dep & density	grs forb lo-shrub-hi conf decid 0% 1 5 15 33 50 67 85 95 99 > <QbSpars <QbDens >QbSpars >QbDens	
Shores - % stable & undercut/overhang max shore depth′	0% 1 5 15 33 50 67 85 95 99 > < .1 .2 .5 .8 1 1.2 1.5 2 2.5 >	
Instream vegetation % vege in reach #lwd pool/reach	mld alg wood root 0% 1 5 15 33 50 >	Lwd-pool #/r 0 1 2 4 8 16 >
Stains & precptates bank or bottom color & extent	Wh R O Y G B I V Blk none sm-patch-lg seep 1- 2- 5- 10- gpm	

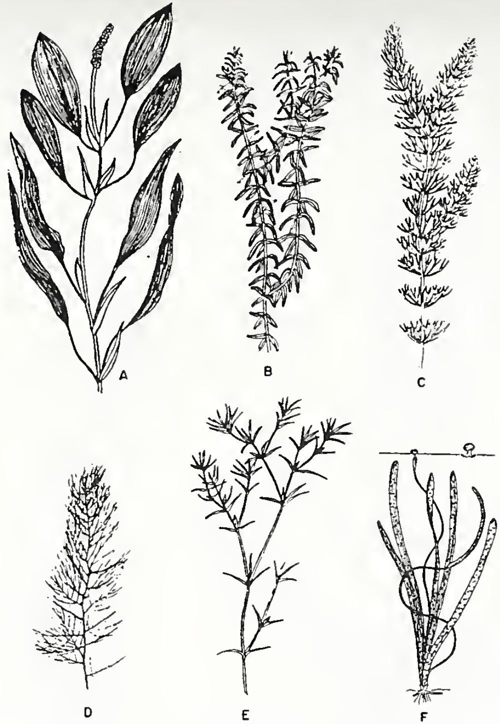


Plate 9. Higher plants: Submersed (all forms illustrated are Spermatophytes).

A—Pondweed, *Potamogeton*	(30-60 cm)	E—Naiad, *Najas*	(60 cm)
B—Waterweed, *Elodea*	(15 cm)	F—Eelgrass, *Vallisneria*	(45 cm)
C—Coontail, *Ceratophyllum*	(30 cm)		
D—Water milfoil, *Myriophyllum*	(30 cm)		

Plate 10. Higher plants: Emersed (all forms illustrated are Spermatophytes).

A—Pickerelweed, *Pontederia*	(60 cm)	C—Spike rush, *Eleocharis*	(30 cm)
B—Sweetflag, *Acorus*	(30 cm)	D—Cattail, *Typha*	(1-2 m)

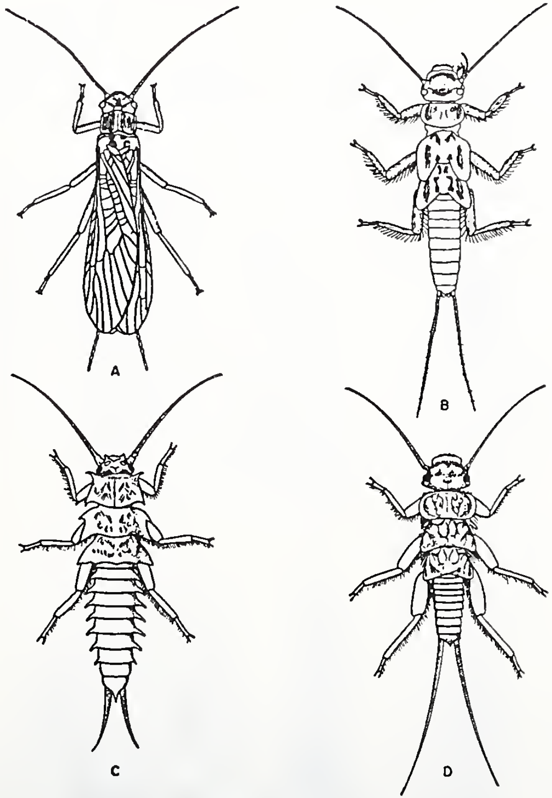


Plate 23. Stoneflies (Order Plecoptera).

A—Adult *Isoperla*, Isoperlidae (14–23 mm)
B—Nymph *Isaperla*, Isoperlidae (10–14 mm)
C—Nymph *Pteronarcys*, Pteronarcidae (10–40 mm)
D—Nymph *Acroneuria*, Perlidae (20–30 mm)

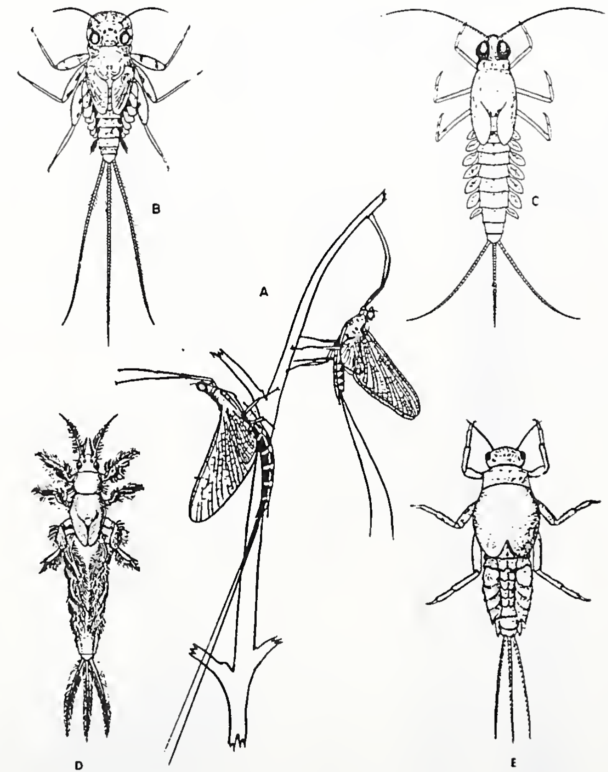


Plate 24. Mayflies (Order Ephemeroptera).

A—Adult mayfly, Heptageniidae (12–18 mm)
B—Nymph *Stenanema*, Heptageniidae (10–14 mm)
C—Nymph *Baetis*, Baetidae (7–14 mm)
D—Nymph *Hexagenia*, Ephemeridae (20–30 mm)
E—Nymph *Ephemerella*, Ephemerellidae (8–15 mm)

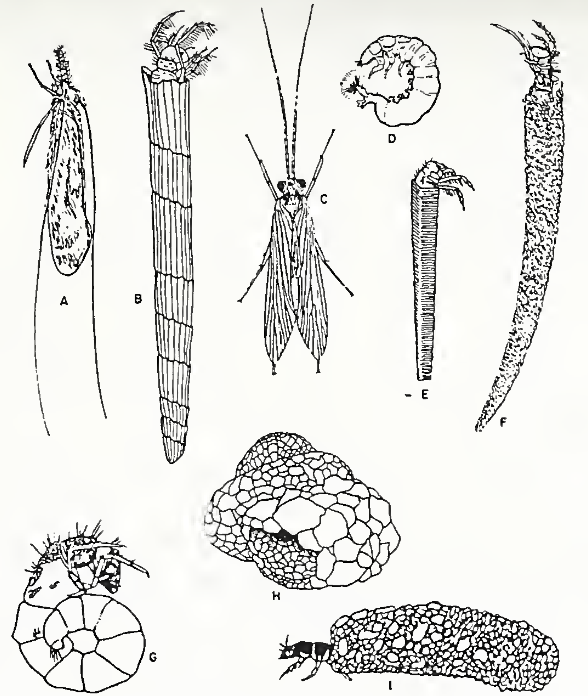


Plate 27. Caddisflies (Order Trichoptera).

A—Adult *Triaenodes*, Leptoceridae (10–20 mm)
B—Larva and case, *Triaenodes*, Leptoceridae (10–14 mm)
C—Adult *Hydropsyche*, Hydropsychidae (20–30 mm)
D—*Hydropsyche* larva, Hydropsychidae (20–30 mm)
E—Larva and case, *Brachycentrus*, Brachycentridae (12–16 mm)
F—Larva and case, *Leptocella*, Leptoceridae (14–18) mm
G—*Helicopsyche* larva, Helicopsychidae (6–10 mm)
H—*Helicopsyche* case, Helicopsychidae (4–6 mm)
I—Larva and case, *Ochrotricha*, Hydroptilidae (4–6 mm)

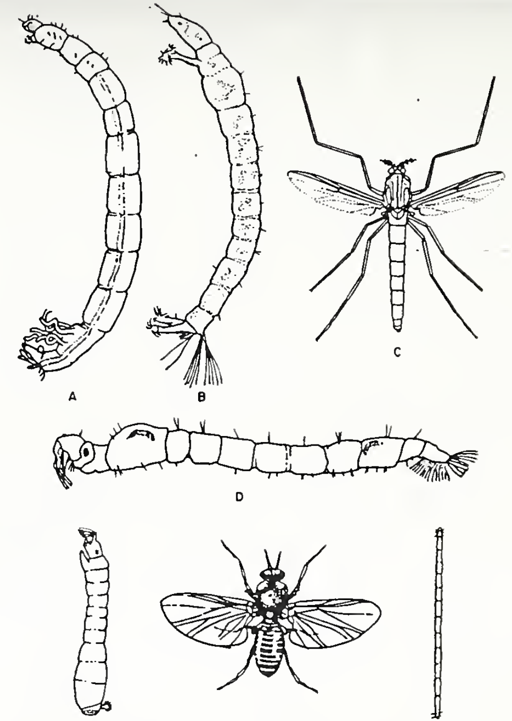


Plate 28. Two-winged flies (Order Diptera).

A—Larva midge *Chironomus*, Chironomidae (5–30 mm)
B—Larva midge *Ablobesmyia*, Chironomidae (5–10 mm)
C—Adult midge, Chironomidae (4–12 mm)
D—Larva phantom midge *Chaoborus*, Culicidae (8–12 mm)
E—Larva black fly *Simulium*, Simuliidae (3–8 mm)
F—Adult black fly *Simulium*, Simuliidae (2–6 mm)
G—Larva biting midge, Ceratopogonidae (3–12 mm)

Diversity Screen Interpretation -

If you can not match the stream reach against a **T**-Standard, the next step is to go directly to the Aquatic Life Health Class table, and make a determination. The following table gives you a first cut by focusing on one Diversity Screen parameter at a time. Read across the table and select the likely Reference condition, then down the Site column to match current or expected condition. If they are the same the table shows Robust (R) health. For Sites that are impacted and of less quality than the Reference, the table shows the decline in health. (If Reference 10 Cobble Count = 128, and Site = 64, then read 'D' from table).

The table is a 'best guess' interpretation, so do not fuss over single factors. Look for patterns among the factors that support or confirm a particular Aquatic Life Health determination. However, this step is not an averaging; if an individual factor is clearly controlling, then it determines the health class.

Temper the table's results with what you know of the area, it's recent climate and management history, and expected impacts in the future. Then, if conditions are not what they should be, the limiting factors suggest a beginning for restoration planning. For example, if Shore depth should be 2' and it is only 0.2', one part of restoration might be to fence-protect the bank, add a log along the bank toe, back slope, and plant willow.

Table - Direct Interpretation of Aquatic Life Health

Site	Reference					
Riffle insects	2May3	St	Case:box-cone	flt-rnd-spr	scf	net
May Stone Caddis	R					
Only 2 of M-S-C	D					
Only 1 of M-S-C	I					
Other macros	P					
barren, no macros	C					

(Sum of 10 cbls)	0	1	2	4	8	16	32	64	128	>128
0	R	C	C	C	C	C	C	C	C	C
1		R	C	C	C	C	C	C	C	C
2			R	C	C	C	C	C	C	C
4				R	C	C	C	C	C	C
8					R	C	C	C	C	C
16						R	P	P	P	P
32							R	I	I	I
64								R	D	D
128									R	A
>128										R

Site	Reference									
(Str bk vege cont) % for both banks	0	1	5	15	33	50	67	85	95	99
0	R	P	P	P	P	P	P	P	P	P
1		R	P	P	P	P	P	P	P	P
5			R	P	P	P	P	P	P	P
15				R	P	P	P	P	P	P
33					R	P	P	P	P	P
50						R	I	I	I	I
67							R	D	D	D
85								R	A	A
95 - 99									R	R

Root depth & density	<QbSpars	<QbDens	>QbSpars	>QbDens
<QbSparse	R	P	P	P
<QbDense		R	I	I
>QbSparse			R	D
>QbDense				R

Shores - % stable	0%	1	5	15	33	50	67	85	95	99
0	R	P	P	P	P	P	P	P	P	P
1		R	P	P	P	P	P	P	P	P
5			R	P	P	P	P	P	P	P
15				R	P	P	P	P	P	P
33					R	I	I	I	I	I
50						R	D	D	D	D
67							R	A	A	A
85 - 99								R	R	R

max shore depth'	0	.1	.2	.5	.8	1	1.5	2	2.5	>
0	R	P	P	P	P	P	P	P	P	P
0.1		R	P	P	P	P	P	P	P	P
0.2			R	P	P	P	P	P	P	P
0.5				R	I	I	I	I	I	I
0.8					R	D	D	D	D	D
1.0						R	D	D	D	D
1.5							R	A	A	A
2.0 & >								R	R	R

Site	!	Reference									
Pools - % in reach	!	0%	1	5	15	33	50	67	85	95	99
0%	!	.R.	P	P	P	P	P	P	P	P	P
1	!	R	.R.	P	P	P	P	P	P	P	P
5	!	R	R	.R.	I	I	I	I	I	I	I
15	!	R	R	R	.R.	D	D	D	D	D	D
33	!	R	R	R	R	.R.	A	A	A	A	A
50	!	R	R	R	R	R	.R.	R	R	R	R
67	!	A	A	A	A	A	A	.R.	R	R	R
85	!	D	D	D	D	D	D	D	.R.	R	R
95	!	I	I	I	I	I	I	I	I	.R.	R
99	!	P	P	P	P	P	P	P	P	P	.R.

max pool dep '	!	<	1'	1.5	2	2.5	3	3.5	4	5	>
<1.0	!	R	A	A	P	P	P	P	P	P	P
1.0	!		R	A	P	P	P	P	P	P	P
1.5	!			R	I	I	I	I	I	I	I
2.0	!				R	I	I	I	I	I	I
2.5	!					R	D	D	D	D	D
3.0	!						R	D	D	D	D
3.5	!							R	A	A	A
4.0	!								R	A	A
5.0 & >	!									R	R

dep' & vel'/s	!	<2d<lv		<2d>lv	>2d<lv	>2d>lv	
(Combinations)	!	all4	any3	2x<d&>d	2x>d	2x<d	any1
all 4	!	.R.	R	R	R	R	R
any 3	!	A	.R.	R	R	R	R
2x (<2d & >2d)	!	D	D	.R.	R	R	R
2x (>2d all v)	!	D	D	A	.R.	R	R
2x (<2d all v)	!	I	I	D	I	.R.	R
any 1	!	P	P	P	P	P	.R.

Stream bank vegetn	!	grass	forb	lo-brush-hi		conf	decid
grass	!	R	P	P	P	P	P
forb	!		R	I	I	I	I
low brush	!			R	D	D	D
high brush	!				R	A	A
conf/decid	!					R	R

Site	!	Reference			
Instream vegetation	!	mold	alg	wood	root
mold	!	R	C	C	C
algae	!		R	P	P
wood	!			R	I
rooted	!				R

% in reach	!	0%	1	5	15	33	50	>
0%	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
5	!			R	I	I	I	I
15	!				R	D	D	D
33	!					R	A	A
50 & >							R	R

Lwd related pools	!	0	1	2	4	8	16	>
0	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
2	!			R	I	I	I	I
4	!				R	D	D	D
8	!					R	A	A
16 & >							R	R

Stains & precptates	!	(bank or bottom color)					
color	!	Wh	R	O Y	G B	I	V Blk
(colors from ==	!	none	iron	copper	leads	oil	unk-org)
none	!	R					
iron	!	D	R				
copper	!	C	C	R			
leads	!	C	C	C	R		
oil	!	C	C	C	P	R	
unk organics	!	C	C	C	C	C	R

color & extent	!	none	sm-patch-lg		seep	1-	2-	5-	10-gpm
none	!	R							
small patch	!	D	R						
large "	!	I	I	R					
seep	!	P	P	P	R				
1- gpm	!	C	C	C	C	R			
2- gpm	!	C	C	C	C	C	R		
5- gpm	!	C	C	C	C	C	C	R	
10- gpm	!	C	C	C	C	C	C	C	R

Watershed name and # - local name and agency code (& any sub-wshed #). Note site vegetation & management prescription. Make local directions & legal location (1"=2000') accurate enough so later visits are possible.

Assessment of Stream Health - compares existing with standard natural conditions. Show existing Stream Health Class and predict Stream Health Class in the next 2 years. Abbreviate health classes as - R robust, A adequate, D diminished, I impaired, P precarious, or C catastrophic.

Profile of Noticeable or Expected CWA Impacts - circle existing conditions for each CWA S*T*O*M*P*E*D impacts; show any trends with an arrow. Summarize impact source, i.e. 'badly rutted road, no waterbars'.

Synopsis and necessary response time - summarize problems; show target date(s) for any emergency action, or remedial work needed to prevent further damage to facilities (including roads) and water courses.

STREAM REACH REVIEW - Clean Water Act Monitoring

Watershed:
Name & # :____
Specific site char & Rx:

Local Directions:

Mer: Twns: Rng: Sec: QtrQtr:

ASSESSMENT of STREAM HEALTH

Stream Health Class		Existing	Expected 2 yr
R	Robust		
A	Adequate		
D	Diminished		
I	Impaired		
P	Precarious		
C	Catastrophic		

PROFILE OF NOTICEABLE OR EXPECTED CWA IMPACTS
(circle existing & arrow trends O-->)

R A D I P C = Sediment:

R A D I P C = Temperature:

R A D I P C = Oxygen levels reduced:

R A D I P C = Metals:

R A D I P C = Poisons:

R A D I P C = Equilibrium shifts:

R A D I P C = Dissolved salts/nutrients:

Synopsis & necessary response time to prevent futher damage:

Expected CWA Restoration Costs - Benefit Lag Time

Failure to meet CWA responsibilities -- as shown by a Stream Health Assessment (Existing or Expected 2 year) of Diminished, Impaired, Precarious, or Catastrophic -- triggers a stream recovery evaluation for each of the CWA S*T*O*M*P*E*D* impacts that fail the 'Adequate' level. **Benefit Lag Time** measures time-out-of-service for resource development economics until recovery of statutory environmental conditions. For the 'with' and 'without' plan condition, develop estimates based on recovery of Robust aquatic life health class and long term productivity.

Benefit Lag Time - 1) identify activities that aggravate the problem; 2) estimate recovery (years) for S*T*O*M*P*E*D Impacts. Guidelines:

S* Rcvry, yr = Storm Runoff Control + Bank Stability + Sediment Flush

- Storm Runoff Control = the greatest time for a,b, or c where
  - a = LFH ground cover recovery, (use LFH G. Cover Recovery Table);
  - b = road erosion control, (use R. Erosion Recovery Table);
  - c = gully & rill stability, (best guess or LFH G.Cover Recvry Table).
- Bank Stability = Extra time as needed for stability after Storm Runoff Control recovery. Extra time is likely for sediment or flow equilibrium shifts, such as sediment spills, water yield increases, or changes in stream flow peak or bankfull duration. Otherwise, assume no extra bank stability recovery is needed.
- Sediment Flush = If Storm Runoff Control &/or Bank Stability need recovery time, then add Sediment Flush to the total. Otherwise, it reflects recovery time from a single massive sediment spill.

  Sed Flush Rcvry, yr = 18 / (Grd * Cmp) where:
  - Grd % = stream gradient,%, (range 0.5% to 10%);
  - Cmp = Competency of Bank Matrls & Assc. Vege; (see Tbl)

Ex: 20% LFH g.cvr, 0.3'LFH, 90% effect. buffer, 2yr road eros ctrl plan. No active gullies; 2% stream grade; Glacial cobble w/ shrub.
Stm RO Cntrl = greater of LFH g.cvr =20, road = 9, or gully = 0
S* Rcvry = (SRC= 20) + (BS= 0) + (SF= 11) = 31 years

T* Rcvry, yr = use best guess on temp recovery; no data.
O* Rcvry, yr = 1 year recovery after BOD source control; no data
M* Rcvry, yr = 20 year ion release after source control; no data
P* Rcvry, yr = 1 year recovery after source control; no data
E* Rcvry, yr = Q & Sed shifts are long term; no data
D* Rcvry, yr = 1 year recovery after source control; no data

EXPECTED CWA RESTORATION COSTS
(Fix diminishd, impaird, precarious, & catastrophic conditn)

Benefit Lag Time, years		Restoration Costs $1000	
No Plan	With Plan	Physical	Chem & Biolgcl

Reviewer & date passed to authority:

LFH Ground Cover Recovery, Years*

LFH depth'	Ground Cover % <20	20	30	40	50	60	70-99%
0.01	106	54	35	19	8	2	0
0.05	92	47	30	17	7	2	0
0.1	78	40	26	14	6	2	0
0.2	55	28	18	10	4	1	0
0.3	38	20	13	7	3	1	0
0.4	27	14	9	5	2	1	0
0.5	19	10	6	3	2	0	0
0.6	13	7	4	2	1	0	0
0.7	9	5	3	2	1	0	0
0.8	7	3	2	1	1	0	0
0.9	5	2	2	1	0	0	0
1.0	3	2	1	1	0	0	0

* LFH Ground cover recovery, yr = (110 * e^-3.5*LFH) * (1 - 2X + X^2)
where LFH = litter, fermented and humus depth (ft)
X = (Grnd Cvr%/70); if 70% or more, Recvry = 0 yr.
Ex: 80% bare soil; undisturbed LFH of 0.5' (6" duff). Rcvry = 10 years

Road Erosion Recovery, Years*

Sediment Yield%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	1	1	1	2	2	2	3	3	3	3	5
2	2	3	5	6	8	9	11	12	14	15	22
5	4	7	10	13	16	19	22	25	28	31	46
10	5	9	13	17	22	26	30	34	38	43	64
15	5	10	15	20	25	30	35	40	45	49	74
20	6	11	17	22	27	33	38	44	49	54	81
25	6	12	18	24	29	35	41	47	52	58	87
33	7	13	19	25	32	38	44	50	57	63	94
50	7	14	21	28	35	42	49	56	63	70	105
67	8	15	23	30	38	45	53	60	67	75	112
85	8	16	24	32	40	48	55	63	71	79	118
90	8	16	24	32	40	48	56	64	72	80	120
95	9	17	25	33	41	49	57	65	73	81	121
99	9	17	25	33	41	49	57	65	73	81	121

* Recvry to annual 0.3 cf/a; ln(0.3/(0.4Syld%^1.7)*TransTime. Where:
Syld% = sediment yield to stream, %.
TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.
Ex: Vege buffer 85% effective, 3 year erosion contrl plan. Rcvry = 15 yr.

Competency* of Bank Materials and Associated Vegetation

Bankland Regime	Bank Protection Raw	Grs	Brs	Trs	Bankland Regime	Bank Protection Raw	Grs	Brs	Trs
Gb	.80	.87	.91	.94	Rr	.89	.94	1.00	.99
Gc	.69	.75	.79	.81	Rb	.86	.91	.96	.96
Gg	.50	.56	.65	.62	Rc	.69	.76	.84	.85
Lf	.27	.33	.45	-	Rg	.48	.55	.66	.67
Jf	.31	.38	.40	-	Rs	.23	.31	.38	.40
Mb	.70	.74	.83	.81	Rf	.24	.31	.41	.43
Mc	.54	.60	.69	.66	Tc	.55	.64	.75	.77
Mg	.37	.46	.54	.53	Tg	.40	.52	.63	.65
Ms	.17	.27	.31	.33	Ts	.19	.28	.37	.40
					Tf	.21	.30	.38	.40

* Rr (Resid bedrock well fractured, colluvial soils) with good brush cover had greatest competency (C=1); all other Bankland Regimes were compared to Rr brush.
G = Glacial; L = Lake; J = jackstraw (like a filled in beaver dam);
M = mass movement deposits; R = Residual materials; T = Terrace deposits.
See channel material size codes for r, b, c, g, s, f.
Ex: terrace deposits of cobble covered with willow shows competence of 0.75

Expected CWA Restoration Costs -- Physical Restoration Costs $1000

Sediment related restoration - the problem with sand is the major loss of aquatic insect production & loss of pool depth for overwintering fish. Actual sand removal -- compared to in-channel redistribution -- seems to be the most cost effective and risk free intrusion into the natural system.

"**S*SWEEP**" Costs = sand cleaning by area to T-std productivity.

**S*SWEEP $** = ImpactArea, sf x sweeper$. Where:

ImpactArea = stream area of bankfull width x impact length, sqft.

sweeper $ = suction drdg, 25hp, ATV, <10' lift $0.12/sqft

"**S*SCOOP**" Costs = volume related; sand removal from sites <5' deep.

S*SCOOP $ = Cubic Yard x scooper $ Where:

Cubic Yard = volume of deposits to be lifted.

scooper $ = basin, backhoe, haul - $8-10/cy

= backwater, backhoe, haul $5-8/cy

= suction drdg, 60hp, roadside, <30' lift - $8-10/cy

= suction drdg, 25hp, ATV, <20' lift - $15/cy

= suction drdg, 8hp, hand, >20' lift - $60/cy

Ex: Stream Bcs1Tc, 21'x3000' impact; **S*SWEEP $** = 63,000 x $0.12 = $7560.

Ex: Stream Abs15Rb, 100 cubyd spill in 7 pools. **S*SCOOP $** = $6000.

Predicting stream clean-up costs from road erosion depends on stream character and Road Erosion Material Yield to the stream (REMY - see Table). Use the larger of either **S*SWEEP $** or **S*SCOOP $** for clean up:

Road S*SWEEP $ = RoadAc x REMY x (152/T-std TSR) x sweeper $

Road S*SCOOP $ = RoadAc x REMY/27 x scooper $

Ex: $202 clean up for 44x1200' road, 20% sedmnt yield, 4yr erosion control plan. T-std TSR is 32; clean up w/ 25hp suction dredge.

Road S*SWEEP $ = 1.21 road ac x 293 x (152/32) x 0.12 = $202

Road S*SCOOP $ = 1.21 " " x 293/27 x 15 = $197

Expected CWA Restoration Costs - Chemical Restoration Costs $1000

Cost data for restoration has not been worked up; go w/ your best guess.

Reviewer & date passed to authority - water quality is the manager's responsibility; your job is to pass along the right information.

==

Reviewer & date passed to authority:

==

Road Erosion Material Yield to Stream, cub ft/road acre*

Sedmnt Yld%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	0.4	0.4	0.4	0.7	0.7	0.7	1.0	1.1	1.1	1.1	1.8
2	1.8	2.6	3.7	4.6	5.8	6.6	7.7	8.5	9.6	10.7	15.4
5	9.6	15.2	21	27	33	38	44	50	56	62	91
10	32	50	70	89	109	129	149	168	188	208	306
15	63	101	140	179	219	258	298	338	377	416	615
20	103	165	229	293	358	422	487	552	617	682	1006
25	150	241	335	429	523	618	713	808	902	997	1471
33	241	387	537	688	840	992	1144	1296	1448	1600	2361
50	489	785	1090	1397	1704	2013	2321	2629	2938	3246	4790
67	804	1292	1793	2298	2804	3311	3819	4326	4834	5342	7882
85	1205	1936	2688	3445	4203	4963	5723	6484	7246	8006	11814
90	1328	2134	2963	3797	4632	5470	6308	7146	7985	8824	13020
95	1457	2340	3248	4162	5079	5997	6916	7835	8754	9674	14274
99	1562	2510	3484	4464	5448	6432	7418	8404	9390	10376	15311

* Cumulative sum of annual road erosion material yielded to a stream starting from initial disturbance and ending with yields less than 0.3 cuft/road ac:

Tot Road mtrl, cf/a = SUM [0.4Syld%^1.7 * e^-(yr/TransTime)] Where:

Syld% = sediment yield to stream, %; f(buffers & expedient traps).

TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.

Ex: Vege buffer 85% effective, 3 year erosion contrl plan, 1024' drain x 45' exposed width. Road mtrl, total cf = (1024x45/43560) x 140 = 148 cf
Same road, 10 yr stability (no erosion plan): (1.06) x 416 = 441 tot cf
Same road, 33% buffer, 10 yr stablty: (1.06) x 5342 cf/a = 5663 tot cf

Remedial plan - defines the watershed treatment plan and implementation schedule. Identify remedial **Objectives** and the completion target date necessary to prevent more damage. Identify specific **Sponsors/clientele** currently affected by the situation and the **values to be protected.** Identify any special or targeted plant or animal species.

Work items - show what & how much has to be done; use the abbreviated list for common channel, road, revegetation, and expedient (temporary) sediment or erosion control measures. Figure necessary costs & special skills. Then add name and telephone of the planner for later questions.

Some Regional unit costs - to be applied with care!		$ low	- high
Clow	Low flow channel structures for sediment contrl, ea	1100	3600
Cnew	Channel construction new/enlarge, cubic yard	15ave	
Crem	Channel debris/sediment removal, $50/lrg woody debris	10/cy ave	
Cstb	Channel/shore bank material stability, cy riprap 10	25 w/revege	
Ebsn	Expedient sediment/debris basin, cy	10 ave	
Ecut	Expedient in-channel trap (trench or trough); no dam	10/cy ave	
Edam	Expedient siphon dam (slant or 'T' pipe), dam	700/<10' high	
Ediv	Expedient storm runoff diversion, linft	100 ave	
Efil	Expedient filter/sorbent material fence, linft	10 ave	
Efur	Expedient log & furrow erosion barriers, cy	12	17
Epit	Expedient small sediment catch 'pit', cy	0	10
Erow	Expedient slash/brush windrow, linft	0	3
Rbar	Water bar, roll dip, & other cross drain repair, ea	25	
Rcul	Bridge & culvert stabilization, ea	500	
Rdrn	Road, trail, & corridor drain ditch stabilztn, linft	0.5	
Rstb	Road fill & bank stability, sqft	1	
Vbfr	Permanent vegetation buffer for sedmnt cntrl, linft	0	0.2
Vcvr	Vege cover density for on-site erosion cntrl, sqft	.1	1
Vexc	Vege protect by livestock exclusion, mi elect= 500,	barb= 3000	

Monitoring - review the need for extra monitoring or intensive field surveys. Direct monitoring efforts to results that are of evidentiary quality & can be used to assess - or restore - CWA Robust stream health. Specify where to sample, who is to do it, which methods, parameters to measure, and frequency. Location is critical; look for sites that are 'weak link' sensitive to early stress or that are expensive to fix:

- Bank Comptncy: raw>grs>brs=trs; s>f>>g>>c>b>r; M >>L=J >G >T >R
  include ad-water, de-water, spill sites, peak & duration changes.
- 1/8 mi (660') downstream of road crossing: culverts > bridges.
- roads that concentrate runoff: design >> temporary > primitive.

```
R E M E D I A L

 Objective(s):      (check-off objective    & target date)
       ___ No action                          \
       ___ Return to prior condition           \
       ___ Meet legal standards                 \ ____________
       ___ Meet administrative standards        /
       ___ Betterment for economic reasons     /

Sponsors/Clientele:
   \\
Values to be protected:
       \\
Work items & amounts needed:  (see abbrv list)
            \\
------------------------------------------------------------
 Clow  Low flow channel structures for sediment control.
 Cnew  Channel construction new/enlarge.
 Crem  Channel debris/sediment removal.
 Cstb  Channel/shore bank material stability.
 Ebsn  Expedient sediment/debris basin.
 Ecut  Expedient in-stream trench or trough cut; no dam.
 Efil  Expedient filter/sorbent material fence.
 Efur  Expedient log & furrow erosion barriers.
 Epit  Expedient small sediment catch 'pit'.
 Erow  Expedient slash/brush windrow.
 Rbar  Water bar, road roll, & other cross drain repair.
 Rcul  Bridge & culvert stabilization.
 Rdrn  Road, trail, & corridor drainage ditch stabilization.
 Rstb  Road fill & bank stability.
 Vbfr  Permanent vegetation buffer for sediment control.
 Vcvr  Vegetative cover density for on-site erosion control.
 Vexc  Vegetation protection by livestock exclusion.
------------------------------------------------------------
Funds and people needed:
        \\
----------------
Planner &  :
Telephone  :
============================================================
```

```
T R A C E      monitoring follow-up

Evaluation Plan for:                        & When:
------------------------------------------------------------
  No follow-up    Trend     Reference    Advance     Effects
------------------------------------------------------------
  Compliance:  Admin  Contract  Permit  WQS  Restore  Emergnc
------------------------------------------------------------
Where:


Who:


How: (photos, samples, transects)


What: (parameters & frequency)


Why:  (expected results, analyses, reports)
```

CLEAN WATER ACT - MONITORING AND EVALUATION

Part 1. Legal Framework

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(prior dates 1986 1987 1988 1989 1990 1991 1992 1993)
January 1994

CLEAN WATER ACT - MONITORING AND EVALUATION
Part 1. Legal Framework

Perspective Failure to meet Clean Water Act requirements in a given watershed, transfers the effective land use control in that watershed to the State water quality control agency. That is the effect of Sec 319 of the Clean Water Act.

CWA S 319, "Nonpoint Source Management Programs", is a new section added in 1987 that generates a biennial State Assessment and Management Program document. The assessment identifies 1) waters that will likely fail or currently fail to meet the Clean Water Act goals; 2) activities that contribute to the problem; and 3) possible best management practices and measures that will improve the conditions for impaired watersheds. The State Management Program is a specific multi-year action plan that schedules coordination and implementation (1).

State water quality plans also must meet certain minimum federal requirements (40 CFR 131.6) before they can be approved by EPA. The plan must set standards that are consistent with CWA goals and procedures; set criteria to protect designated uses; must provide for antidegradation; must show official certification; and provide sufficient scientific background to support program implementation.

In times of dwindling resources and expanding litigation, the best approach is to conduct activities in ways that the Clean Water Act goals are achieved; that small problems are identified early and fixed; and to rationalize pollution control expenditures in terms of measurable results.

In a broad context, land use planning and NEPA evironmental analysis continues to demand detailed analysis of water quality issues (2 3 4 5 6 7 8). Failure to respond adequately to legal mandate is an easy challenge that can, and has, upset plan implementation (9). The "enforcement program for mitigation" in the Record of Decision (40 CFR 1505.2) is particularly exposed to challenge; it must be technically competent, legally defensible, and accurately reported.

PLANNING FOR WATER QUALITY

Under the auspices of the Clean Water Act, State water quality agencies have authority to ask federal agencies to provide information for the biennial water quality assessment report. The heart of the report is a basic inventory of biological health for all streams and lakes and the degree to which designated beneficial uses are threatened in the future (10 11).

An additional planning problem is how to insure that the necessary information is available in the decision - and judicial - process. As is common to the planning experience, both the technical and legal basis is changing in ways that make past efforts inadequate. Starting with the most demanding set of requirements to be met in a court room setting will help focus attention on cost effective data analyses as a means of reducing adverse judicial rulings stemming from inadequate preparation. The NFMA regs at 36 CFR 219.23(d) precisely defines the planning linkage to the Safe Drinking and Clean Water Acts and provides a foundation for watershed related analyses, planning, and reporting criteria (12).

Monitoring has a primary directive to determine how and where pollutants are brought together, how and where they are dissipated, and to evaluate the resulting effects on inter-related physical, chemical, and biological systems. This directive from the Clean Water Act is echoed by NEPA/EIS requirements for analysis of cumulative effects (13 14). From this viewpoint, the choice of monitoring and evaluation tools must be driven by the routine measurement of appropriate physical and chemical parameters and the associated effects on aquatic ecosystem diversity, stability, and productivity.

Current experience with the assessment of watershed cumulative effects and implementation monitoring suggests the need to respond to four primary concerns:

1) key water quality impacts;
2) temporary nature of acceptable environmental changes;
3) antidegradation; and
4) watershed geomorphic equilibrium.

Key Water Quality Impacts

The question of Congressional intent is paramount. Compiling the most demanding set of planning requirements starts with the law and legislative history and the realization that Congress intended that the various environmental acts, such as NEPA and the Clean Water Act, to fit together (15 16).

Table 1.1 "Water Quality Impacts" is a composite list of specifics abstracted from legislative histories for 1965, 1972, 1977, and 1987 Clean Water Acts, National Forest Management Act, Wild and Scenic Rivers, and the Multiple Use Sustained Yield Act (17 18). This water quality impact list defines the scope and foundation for a long term watershed and hydrology framework in both monitoring and cumulative effects analysis. The challenge is to build a few good tools that will serve both planning and implementation stages effectively.

Table 1.1 - Water Quality Impacts
(From U.S. Code Congressional & Administrative News: [yr:pg] and U.S. Code)

Impacts to be discussed in reference to:

* key species, natural temperature and flow patterns.... [72:3717; 33 USC 1314]
* Concentration and dispersal of pollutants (w/ by-products) through biological, physical, and chemical processes and any related changes in the diversity, productivity, or stability.... [72:3716; 33 USC 1314]
* Description of factors related to rates of eutrophication; organic material accumulation; and inorganic sediment accumulation.... [72:3717; 33 USC 1314]
* Dissolved oxygen conditions needed by location, species, and activity (hiding cover, propagation, food supply, reproduction).... [77:4366; 33 USC 1311]
* Effects of Road construction, use, and maintenance on the biological character or flow, reach, and circulation.... [77:4401; 33 USC 1344]
* Factors needed for restoration of the natural chemical, physical, and biological integrity.... [72:3715; 33 USC 1314]
* Effects on hydrologic cycle and storm runoff [72:3719; 33 USC 1314]
* Accurate assessment and comparison of existing condition to water quality objectives to be met.... [72:3681 33 USC 1314]

Decisions that affect water quality are made in a legal framework that is heavily modified by regional and local politics. Water quality is commonly seen as a constraint or interference with 'business as usual' rather than a positive element for long term economic stability. However, case law demonstrates that taking short cuts in either planning or implementation has substantial risks for the organization as well as the individual:

** In construing Federal Water Pollution Act Amendment of 1972, the guiding star is the intent of Congress to improve and preserve the quality of the Nation's waters and all issues must be viewed in light of such intent. 543 F.2d 1198; 612 F.2d 1231; 540 F.2d 1023; 97 S.Ct 1340; 97 S.Ct 1672.

Committing large amounts of resources to following EPA and state agencies around in ever widening regulatory circles may be less effective use of scarce resources than developing procedures to identify and correct problems. High on the list would be to train field people in the best ways to stay out of trouble. Using law & legislative history as the basis of such effort is a good long term strategy (19).

** State authority to allocate water does not take precedence over legitimate and necessary water quality considerations. 530 F.Supp 1291, 693 F.2d 156.

The water developers would have you believe otherwise. While it is national policy not to interfere with the State's authority to allocate water, the Act is clear about federal, state, and local agencies working together to develop comprehensive solutions to prevent, reduce, or eliminate pollution in concert with water resource management programs (20). Antidegradation standards also apply to water resource development occurring after Nov. 28, 1975. Water quality and stream health evaluations are still essential elements of planning (21).

The Forest Service is responsible for the recovery of any and all water quality degradation on National Forests. That responsibility does not transfer with the water rights or special use permits.

** CWA is broad and remedial, and is intended to restore and maintain natural chemical, physical, and biological integrity. 438 F.Supp 945.

The expense of restoring stream damage is about 20 times greater than the cost of preventing the problem to start with. A major court award for fixing a problem that could have been prevented is an embarrassing way to torpedo a good production oriented budget.

** Agents, even government agents, may be subject to liability for wrongful acts either in tort or in contract. 728 F.2d 1006.

Its called personal exposure to liability by exceeding the authority vested in the job. In relation to water quality, plans need to be clear about what is going to be done - and budgeted to do it. Field people becoming lax on administration duties can create an immense liability for themselves (22 23). For the organization, only rarely has the 'lack of budget' excuse been a successful defense.

Temporary Nature of Acceptable Environmental Changes

Maintenance of ecological integrity requires that any changes in the environment resulting in a physical, chemical or biological change ... be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original. [3742 USCC&AN 1972].

Because temporary upsets are forgiven, the monitoring problem is with long term effects on processes and maintenance of functions (24). If ecological integrity is accepted as being an unimpaired functioning of a community complex; then function reflects 'the normal and specific contribution of a bodily part to the economy of a living organism' (Webster). Included in 'economy' is also the sense of efficiency which blends well with other Congressional intent that a pristine condition minimizes the burden to mankind in maintaining a healthy and stable biosphere essential to well-being of human society. [3742 USCC&AN 1972] (25).

The kinds of functions most likely to be upset for long term include changes in sediment regimes, upsets in temperature regimes, upsets in oxygen and oxidation regimes, the inclusion of metal contamination within basic life processes, generic or specific poisoning of community members, upsets or shifts in watershed geomorphic equilibrium, and upsets within dissolved chemical regimes such as nutrients and salts. (26 27 28 29 30 31 32). From the standpoint of monitoring and evaluation of these functions, there are two things to do:

> refine energy and material transport functions into mathematical relationships for the major natural processes likely to be impacted; and

> describe pristine conditions in terms of measurable chemical, physical, and biological parameters.

The list of 'Water Quality Impacts' from Table 1.1 has been re-arranged to better spotlight the functions and effects likely to occur from normal physical processes (33). Table 1.2 "Measures of Water Quality - Functions and Effects" continues to be based on legislative history.

Table 1.2. Measures of Water Quality - Functions and Effects

1. Concentration of pollutants thru physical processes.
2. Dispersal of pollutants thru physical processes.
3. Rates of inorganic sediment accumulation.
4. Eutrophication & organic accumulation rates; pollutant concentration and dispersal through biological and chemical systems.
5. Effects on key species, natural temperature patterns, & dissolved oxygen conditions (food, propagation, cover).
6. Effects on natural stream flow patterns (includes road and corridor effects on reach, flow, and circulation).
7. Effects on aquatic ecosystem stability & diversity.
8. Effects on aquatic ecosystem productivity.
9. Effects on hydrologic cycle and storm runoff.
10. Stream health restoration and recovery rates.
11. Comparison of actual condition to Congressional objectives.
12. Comparison of water samples to State water quality standards.

Antidegradation

State water quality plans must meet certain minimum federal requirements (40 CFR 131.6) before EPA can approve the State plan. These plans must include standards consistent with Clean Water Act goals and procedures; must provide an analysis to support standards; must set criteria sufficient to protect designated uses; must provide for antidegradation (34); must show official certification; and provide sufficient scientific background to support program implementation.

Antidegradation policies and implementation methods adopted by States are approved by EPA using the following minimum criteria (40 CFR 131.12):

1 Existing uses actually attained in the water body on or after November 28, 1975, shall be maintained and fully protected. Designated uses can not be assigned that are less than existing uses.
2 If the water body is of Outstanding Natural Resource water characteristics, i.e. National and State Parks, wildlife refuges, exceptional recreation or ecological significance, designated uses and water quality standards must reflect existing quality and can not be lowered.
3 If the water body is not classed as outstanding and if statutory and regulatory requirements for point and nonpoint sources have been achieved, then the State may sanction the lowering of water quality standards (but not designated uses) to achieve important economic goals.

Minimum level designated uses are deemed attainable if they can be achieved under existing conditions by imposition of effluent control and best management practices. As such practices are applied, improvement in diversity, ecosystem stability, or productivity raises the bottom level against which compliance to antidegradation is then measured. Since existing uses are dependent on existing conditions, the deterioration of limiting chemical or physical factors is evidence that the existing use has degraded or will degrade. Limiting factors listed in 40 CFR 131.10g (paraphrased) include:

- naturally occurring pollutants that prevent a higher use; or
- seasonal water flow conditions that prevent a higher use; or
- human caused damage that is better left alone; or
- hydrologic modifications and operations that prevent a higher use; or
- natural physical conditions (substrate, cover, flow, depth, pools, riffles, and the like) that prevent a higher use; or
- where current effluent performance standards are not satisfactory.

For practical considerations, the condition and suitablity of substrate, cover, flow, depth, pools, and riffles to support existing or designated uses is a threshold determination in the NEPA sense because of the antidegradation test. There may also be NEPA threshold determinations related to exemptions or permits under CWA S 404. The failure to maintain the physical conditions necessary to support existing uses would constitute 'significant degradation' under regulation at 40 CFR 230.10 and measured under 40 CFR 230.11(g) "Determination of cumulative effects on the aquatic ecosysytem" and 40 CFR 230.11(h) "Determination of secondary effects on the aquatic ecosystem" (35).

The Forest Service also has an affirmative duty to harvest timber "only where" water conditions or fish habitat are not likely to be "seriously and adversely" affected and cannot abdicate its separate duty under NFMA, even if state standards might allow it to do so. NFMA, therefore, appears to create a federal prohibition equivalent to a federal antidegradation policy for Natl Forests (36).

Watershed Geomorphic Equilibrium

The Forest Service has major watershed responsibilities for the protection of water courses and land productivity (37 38). Legislation from the 1897 Organic Act through the National Forest Management Act to the Clean Water Act and Executive Orders all contribute to the definition of water and watershed responsibilities. In particular, the objectives of 'physical integrity' from the Clean Water Act and 'favorable condition of waterflow' from the 1897 Organic Act are specific mandates for maintaining stream channel conditions.

Watershed geomorphic equilibrium between sediment transport and stream power is a necessary and major condition of physical integrity and stream channel maintenance. Natural alluvial stream channels are self-formed and self-maintained and reflect the prevailing flow and sediment regimes. Disruption of the natural regime has long term consequences: channel aggradation or degradation, extensive bank erosion, new meander patterns, wide shallow cross sections, loss of pool area, vegetation encroachment, and reduced flood flow capacity. Once started, such a destructive cycle can last decades or even centuries before the natural equilibrium is re-established.

Aside from the legal ramifications of failure to comply with the Clean Water Act and the 1897 Organic Act, there are numerous examples where impaired natural processes have generated economic loss, job loss, reduced public health, lower quality of life, loss of future options, and large clean-up or restoration costs.

REPORTING ON WATER QUALITY

The Statewide Water Quality Assessment (CWA S 319 report) is the lead document for assessment, implementation, and establishing priorities for monitoring, NPDES permits, compliance and enforcement, use attainability studies, and multi-agency coordination. The report has a watershed focus and includes a problem analyses of current trends, a summary of statewide waterbody health by watershed stream miles and lake acres, risk assessment of selected watersheds and activities, and a summary of watershed damage control programs and improvement actions to be taken.

Watershed Problem Analysis

How and what the State may use as criteria for problem selection and analysis of impaired watersheds will likely change from year to year. The best way to stay off the 'impaired watershed list' is to anticipate potential problems and take preventative measures. In particular, those activities and special use permits that bear heavy liability need to be singled out and strictly controlled.

In the 1970's the EPA contracted Battelle Columbus Laboratories to make an expert analysis of current and future pollution problems with the purpose of guiding EPA's research and development in pollution control efforts (26). The analysis was based on the seriousness of amounts generated, persistence, mobility, pervasiveness, physiological risk, research needs, people affected, and complexity of technological, social, environmental, legal, and political issues. The value of this comprehensive analysis is that it can be used to keep monitoring focused on the tough problems and not let it slip into trivia. Table 1.3 "Summary of Serious and Complex Pollution Problems" is used later as a structure for the focus of monitoring programs on watershed problems.

Table 1.3 Summary of Serious and Complex Pollution Problems

Impacts of New Energy Initiatives - many new use and extraction technologies (coal gasification, liquefaction, geothermal, nuclear, solar power; coal cleaning and desulfurization; oil shale and tar sands processes). Impacts include thermal discharges, radioactive waste, heavy metals, toxic organics, and ever greater volumes of coal residues, washes, ash and acid mine drainage.

Geophysical Modification - impacts include acid mine drainage, strip mining, dredging, siltation, erosion, vegetation destruction, underground explosives, stream channel modification, stream flow diversions, and water impoundments.

Trace Element (mainly heavy metal) Contaminants - major concern because of multiple pathways, diverse sources, difficult fugitive capture, hazardous organo-metallic conversion, bioaccumulation, and low concentration effects on natural system succession. There are major unknowns in recovery mechanisms, safe levels, and impacts from overexposure as well as genetic, mutagenic, and teratogenic effects from long term low-level exposure.

Proliferating Hazardous and Toxic Chemicals - concern caused by DDT, dioxin, hexachlorobenzen, and other toxic contamination of ecosystems as well as food and water sources. Laboratory and field surveys show the problem is growing.

Emissions from New Automotive Fuels, Additives, and Control Devices - vehicles will use new fuel blends, have catalytic exhaust convertors, and run with low-polluting engines. The use of new materials and ultimate disposal all have major but largely unknown consequences.

Disposal of Waste Sludges, Liquids, and Solid Residues - concerns of what to do with the enormous volumes of frequently contaminated and hazardous residues generated by pollution control efforts. Controlled land disposal will continue to be used to a greater extent. But creative alternatives are needed.

Critical Radiation Problems - while nuclear radiation releases are serious, they are only a part of the total radiation spectrum. Exposure to greater intensities of non naturally occurring wavelengths has serious implications.

Fine Particulates - ranks high in terms of (a) direct health effects, (b) a multiplicity of sources, (c) the relative persistence and pervasiveness of fine particulates once they are emitted, and (d) the difficulty of control before, and mitigation after, emission. The health hazard can be substantial.

Expanding Drinking Water Contamination - potable water treatment is directed at a relatively narrow group of contaminants; however, number and type of substances entering water supply sources have increased. Contaminants include all ranges of heavy metals, organics, biologicals, and radioactive elements.

Irrigation (Impoundment) Practices - large areas are used for storage and distribution. Salt, heavy metal, alkali, or acid buildup in soil can damage drinking water supplies and with time decrease soil productivity.

Flinn, J. and R. S. Reimers. 1974. Development of Predictions of Future Pollution Problems. Battelle Columbus Laboratories. EPA 600/5-74-005.

Watershed Waterbody Health

How and what the State may use as criteria for analysis of waterbody health may change from year to year. The best way to avoid the confusion caused by changes in defintions is to define waterbody health in sufficient biological detail that is both generic in language as well as legally based. Then stream miles and lake acres can be added up to whatever grouping the State requests with less hassle.

Further, for monitoring to be usable in a land mangement context, the various effects and functions need to be 1) easily summarized and 2) useful through the entire range of biological conditions. Four steps were used in defining waterbody health: 1) select a useful number of categories and titles that define incremental risk; 2) define each category using aquatic diversity and ecosystem stability descriptors; 3) define each category using aquatic productivity measurements; and 4) combine both into an ecological stream health classification based on the response of biological communities to environmental changes. These steps are treated in more detail as follows:

Categories and Titles - A review of several ecological and water quality classification systems (39) indicated that 6 levels of definition have enough flexibility to scale both impact and incremental risk in system response from complete health to ecosystem death. The term "resource use" means the interaction of human use with natural impacts including drought, wind, insects, disease, fires, floods, and land slides. Although none of the classifications used these exact words, each had their own counterpart:

Robust - having or exhibiting strength or vigorous health; flourishing condition. Syn: healthy (Webster). No resource use changes are required; all systems are in balance; natural processes are effectively assimilating management generated effects.

Adequate - sufficient for a specific requirement; lawfully and reasonably sufficient. Syn: sufficient (Webster). Resource use with a few areas sacrificed or lost to production to locate facilities and effectively manage the area. The impact is small and takes up only those sites required for effective use of entire area, such as a mixing zone below a effluent discharge point or the stream destruction at road crossings. Adequate means legally changed to lesser quality; but not carte blanche authority to reduce Robust health. No agency has that authority.

Diminished - made smaller; lessened; reduced; (as in size, degree, importance, etc). Syn: decrease (Webster). Natural systems are stressed in ways that point to much more severe decline if management does not back off. The damage is relatively slight and natural systems are expected to recover rapidly if given the chance.

Impaired - made worse by or as if by diminishing in some material way; damage. Syn: injure (Webster). Natural systems are clearly pushed too hard. The damage is substantial and natural systems are expected to eventually recover previous diversity and productivity if given enough time.

Precarious - characterized by a lack of security or stability that threatens with danger. Syn: dangerous (Webster). Natural systems have been pushed to the limit. The natural system ingredients are still in place; recovery is possible with substantial costs for restoration. Further stress will collapse the system.

Catastrophic - utter failure; calamity. Syn: disaster. (Webster). Natural systems have been pushed beyond their limits and the existing site quality has been destroyed. The land management phase is now concerned with failure and liability with substantial resources going to on- and off-site damage control and to rebuild the natural system.

Aquatic Diversity - Using these six general classes, aquatic diversity can be merged with ecosystem stability under the concept that a stable ecosystem tends to have all niches fully occupied by appropriate species; no species become extinct; and none reach epidemic proportions for long enough to destroy the niches of other species. (Preston 1969 Wildland Planning Glossary p65 (40)). The classification scheme developed by EPA (41) provides a suitable framework. The EPA scheme uses a community structure approach to incorporate trophic structure, stability, and diversity. Table 1.4 "Aquatic Life Health Classes" displays the class attributes.

Table 1.4. Aquatic Life Health Classes *

Class	Attributes
Robust	Comparable to the best situations unaltered by humans; all regionally expected species for the habitat and water body size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Adequate	Fish and macroinvertebrate species richness somewhat less than the best expected, especially due to loss of most intolerant forms; some fish species with less than optimal abundances or size distributions; trophic structure shows some sign of stress.
Diminished	Fewer intolerant forms of fish and macroinvertebrates are present. Trophic structure of the fish community is more skewed toward an increasing frequency of omnivores; older age classes of top carnivores may be rare.
Impaired	Fish community is dominated by omnivores; pollution tolerant forms and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased individuals may be present. Pollution tolerant macroinvertebrates are often abundant.
Precarious	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, physical damage, and other anomalies regular. Only tolerant forms of macroinvertebrates are present.
Catastrophic	No fish, very tolerant macroinvertebrates, or no aquatic life. Ecological upset and collapse; retrogression.

* EPA. 1983. Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses. Office of Water Regulations & Standards, Wash. D.C. 20460. Pg V-4. (EPA names were converted to these class adjectives.)

Aquatic Productivity - The evaluation of productivity in stream health starts with the concept of ecological carrying capacity: "the number (or weight) of organisms of a given species and quality that can survive in, without causing deterioration of, a given ecosystem through the least favorable environmental conditions that occur within a stated interval of time". (Ford-Robertson 1971 Wildland Planning Glossary p40 (40).

The numerical thresholds for six production classes are based upon long term natural conditions. Production changes are indexed on a ratio scale of 0 to 1 calculated as projected (or existing) divided by expected production under long term natural - **Reference** - conditions (41). The terms are commensurate, the ratio dimensionless, and "1" is the best ratio. The production ratios are:

Robust	production	ratio range:	1.0 to 0.9	of Reference Condition.		
Adequate*	"	"	"	<0.9 to 0.7	"	"
Diminished	"	"	"	<0.9 to 0.7	"	"
Impaired	"	"	"	<0.7 to 0.5	"	"
Precarious	"	"	"	<0.5 to 0.3	"	"
Catastrophic	"	"	"	<0.3 to 0	"	"

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* Adequate only applies to legally impacted stream reaches.

Stream Health Classes - Stream health is a combination of ecosystem stability and diversity as defined by the aquatic life health class; and production as defined by the ecological carrying capacity ratio. The combinations for both dimensions are shown in Table 1.5 - Stream Health Classes. Notice that the class is defined by the lowest of the two dimensions. For example, a stream with 'Robust' aquatic life and 'Diminished' production would be declared 'Diminished' Stream Health. The two scales are not averaged; the basic idea of defining limiting factors is valuable for understanding restoration factors and preventing further damage.

Table 1.5 **Stream Health Classes**

(Combination of aquatic life health and carrying capacity ratios)

Aquatic Life Health Class	Ecological Carrying Capacity Ratios 1.0-0.9	<.9-0.7	<.9-0.7	<.7-0.5	<.5-0.3	<.3
Robust	ROBUST	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Adequate	ADEQUATE*	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Diminished	Diminishd	------------------	------------------>	Impaired	Precarious	Catastrph
Impaired	Impaired	----------	----------	---------->	Precarious	Catastrph
Precarious	Precarious	----------	----------	----------	---------->	Catastrph
Catastrophic	Catastrph	----------	----------	----------	----------	---------->

* Adequate only applies to legally impacted stream reaches.

Watershed Monitoring List

States can request copies of agency monitoring plans for use in the Water Quality Assessment and Management Program. For impaired watersheds, the State may elect to review program effectiveness and, perhaps, require specific monitoring.

Good monitoring plans are also needed by agency management for budgeting and project control (37). Broad scale generic statements have not served well in judicial arguments under the Administrative Practices Act or Sec 505 "Citizen Suits" of the Clean Water Act. Under S. 505 the issue is a factual one of whether there has been compliance to the Clean Water Act. The burden of demonstrating compliance is on the agency (as actor) and must be supported by an objective evidentiary standard of "considerable record" [3745 & 3746 USCC&AN 1972].

Evidentiary Standard - Its important to understand what evidentiary quality data entails so that routine efforts can show well under judicial review. The following questions, obtained from Charles Lennahan (15 42) are used to evaluate the expected quality of a given monitoring plan. A well written document with references to show good science and an operation schedule is valuable. Haphazard or sloppy monitoring, especially if it fails statistical, mathematical, or procedural validity, are likely to be a waste of time and money (43 44).

- Have data collection methods been standardized and applied consistently?
- Have analytical methods been standardized and applied consistently?
- What type of data, accuracy, and detection limits are required?
- What time and space is represented?
- What frequency and distribution is represented?
- What is the physical, chemical, or electrical basis of the equipment?
- Does equipment measure what is required?
- Does it have the required accuracy under field conditions?
- How many units of equipment are required?
- Are maintenance and calibration provided for?
- How and when will data be collected?
- How will data be recorded and stored?
- What is the introduced error?
- Is the analysis statistically, mathematically, and procedurally valid?
- Is interpretation logically correct and appropriate to the objective?
- Are the people involved with equipment and collection competent?
- Are the people involved with analysis and interpretation competent?

Landscape Scale - Management and decision control in the planning stage as well as the implementation stage operate at several levels of landscape spatial resolution and reporting. These range from large area plans down to site specific projects. Vertical integration based on 4 levels - **basin, watershed, reach, site** - is also appropriate for evaluating Table 1.2 "Measures of Water Quality - Functions and Effects" and watershed cumulative effects.

> **Basin level**. The basin is comparable to the Cataloging Unit used by the Water Resource Council for national planning. The Basin is used by many states as the reporting unit for the annual waterbody assessment report as well as a framework for assigning water quality standards, prioritizing problem watersheds, and planning for water resource development (45 46).

> **Watershed level.** The watershed is a subdivision of a basin and usually of 4th order or smaller size. Watersheds are selected to help summarize and prioritize local information about existing or potential waterbody quality

problems. Cumulative effects and antidegradation are primary concerns for watershed response inventories and predictive models (2 47 48).

> **Reach level**. A reach is a subdivision of a watershed that tends to be uniform with respect to stream flow, depth, area, and slope. Reaches serve best when they are sensitive to early changes or close enough to land use activities for monitoring and evaluation purposes. The content of a reach survey is dictated by questions raised in prior monitoring, the need to support restoration planning, or to verify watershed response predictions.

> **Site level**. A site is a subdivision of a reach for which particular factors are to be measured. The value of a well done site study is the ability to serve as a bench mark in time and for extrapolation to other sites and reach conditions.

Monitoring Purposes - Good monitoring efforts require carefully identified technical objectives (49). Most monitoring plans reviewed between 1981 and 1987 can be grouped into 1 of 5 basic purposes. Current regulatory and legal mandates can be achieved by using a combination of these 5 monitoring purposes:

> Trend monitoring--a long term data collection effort designed to detect statistical trends and to compare current events with long term patterns.

> Reference monitoring--designed to describe and quantify physical, chemical, and biological parameters of pristine (or best available) conditions in representative ecological situations.

> Advance warning system monitoring--a continuous, on-going effort to identify conditions that are or could lead to environmental deterioration, litigation, or unnecessary restoration costs.

> Compliance monitoring--comparison of project oriented activities and resource conditions with established standards or requirements.

> Effects monitoring--determination of the effects of human activities on the relationships among climate, geology, topography, vegetation, biota, and soil variables; measured in terms of selected physical, chemical, and biological factors of the target ecosystem.

Best Management Practices -- Subject to CWA S208, S304, S319, S404, and EPA guidelines pursuant to S304, BMP's are official pronouncements by the state water quality agency developed through a comprehensive problem analysis, examination of alternative practices, and appropriate public participation. The state is responsible for the process of identifying problems, devising control measures, assessing effectiveness, and mandating BMP's to be used on watersheds assessed to be impaired or threatened within the meaning of CWA S 319 (1 50).

Evaluation of BMP effectiveness will include physical, chemical, and biological parameters appropriate to CWA goals including major unknowns and associated risks from pollutant levels and transport paths, wet weather impacts, natural background conditions, aquatic ecosystem functioning, and cumulative effects. If a given BMP is not effective, then the responsible agency must modify the BMP and demonstrate improved effectiveness.

Section 404 Exemptions - CWA S 404 regulates dredge or fill activities and any related discharges into "waters of the U.S." The purpose is to protect those waters by preventing pollution (51). There are 3 forms of regulation: situations which claim an exemption, situations for which a general permit is satisfactory, and situations for which an individual site specific 404 permit is necessary.

In order to claim an exemption, several criteria must be met. Neither the EPA Guidelines nor the Army Corps of Engineers administrative procedures wish to re-regulate activites that are already in compliance with other appropriate sections of the CWA. However, if the criteria are not being met, then the activity is not exempt and the actor must obtain a permit.

The various exemptions and conditions are found at CWA S 404(f)(1):
Subsection (A) relates to silvicultural activites;
" (E) relates to road construction and maintenance activites;
" (F) relates to all manner of land use activites covered by BMP's.

The exemption for land use activities, including silviculture, is determined by compliance with best management practices contained in state water quality programs approved by EPA under CWA S208 and S319 (52). The COE baseline BMP's for roads (33 CFR 323.4) are also mandatory. There are two critical points:

1) best management practices must comply with S 404 (b)(1) guidelines (40 CFR 230) which carry a presumption toward zero discharge; and
2) any activity requiring best management practices can be terminated or modified for cause, including violation of any condition of the practice (53).

Situations are too common where the exemption was claimed, but BMP's were then not installed because their extra cost made them "impracticable" or "not feasible". This is particularly true of road construction and maintenance. However, under S319, BMP's must be installed to reduce, to the maximum extent practicable, the level of pollution resulting from land use activities (54).

The test for compliance for roads under the S 404(f)(1)(E) exemption are:

1) that flow and circulation patterns are not impaired;
2) that chemical and biological characteristics are not impaired; and
3) that effects on the aquatic environment are minimized (55).

If effective BMP's can not be achieved, then the exemption disappears and the regulations that relate to a general or individual permit apply. This could easily escalate typical EA's with road construction and maintenance into EIS's because of the CWA S 404 permit requirements. Failure to obtain the necessary permits is an act of non-compliance and accelerates the risk of legal action.

Application of State Water Quality Standards - CWA S 313(a) requires federal agencies to comply with state water quality standards. The FS has argued that BMPs serve as a proxy for state water quality standards and thereby relieve the agency of the obligation to determine if standards are actually being met. This argument was rejected by the 9th Circuit Court of Appeals in the case known in the FS as the "G-O Road". The Court ruled that land management had to meet state water quality standards and that BMP's were merely a means to that end, but not an end in themselves (56).

The 9th Circuit ruling in "G-O Road" supports the S 404(b)(1) regulations issued by EPA. Among other things, 40 CFR 230.10(b) prohibits a discharge if it causes or contributes to violation of state water quality standards.

The NEPA regulations in 40 CFR 1500-1508 control a major part of the EIS analysis and the decision process itself. The role of mitigation is to contribute to the least environmentally damaging, practicable alternative. Mitigation must be directly related to the impacts of the proposal, be appropriate to the scope and degree of those impacts, and be reasonably enforceable.

NEPA S 1505.2(c) declares that the Record of Decision shall contain enough of a **monitoring and enforcement program** to ensure that mitigation conditions are met. The Record of Decision specifies the mitigation and may include requirements:

- To minimize adverse project impacts, such as by timing of construction activities or incorporation of low-impact operation and maintenance; or
- To meet legal requirements, such as by compliance to CWA S 401 Water Quality Certification or to Sec. 7 of the Endangered Species Act; or
- To not diminish public interest, such as by requiring mitigation success before that phase of project action is initiated.

The Record of Decision evaluates the degree to which mitigation is enforceable and concludes that mitigation will be implemented or explains why it will not be implemented. The approving agency bears the burden of obtaining compliance with the Record of Decision, including all aspects of mitigation. If there is a federal permit, the Applicant is responsible for complying with the permit conditions and the permitting authority is responsible for enforcing the permit conditions. Monitoring and evaluation requirements are also specified in the National Forest planning regulations (57).

With regard to the monitoring and enforcement question, current experience suggests that when money has to be spent for environmental reasons, any step, standard, or procedure that carries an expense is likely to be challenged. With that in mind, the Record of Decision needs to be fully supported by a strong, crystal clear, and legally defensible monitoring and enforcement program.

One common way to stop a project is to ask the Court for an injunction. The basis for injuctive relief is irreparable injury* and the fact that money will not make it better (857 F.2d 1307; 107 S.Ct.1396). The presumption is that environmental injury, by it's nature, can seldom be adequately remedied by money damages and is often of permanent or long duration; i.e. irreparable. (840 F.2d @722; 107 S.Ct. @1404). Thus, when environmental injury is sufficiently likely, the balance of injury will usually favor the issuance of an injunction to protect the environment. The court must expressly consider the public interest and the record must be "adequate". (851 F2d @1157).

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* Irreparable injury. This phrase does not mean such an injury as is beyond the possibility of repair, or beyond possible compensation in damages, or necessarily great damage, but includes an injury, whether great or small, which ought not to be submitted to, ...or inflicted,...; and which, because it is so large or so small, or is such a constant and frequent occurrence, or because no certain pecuniary standard exists for the measurement of damages, cannot receive reasonable redress in a court of law. Wrongs of a repeated and continuing character, or which occasion damages that are estimated only by conjecture, and not by any accurate standard, are included. (Black's Law dictionary 5th ed).

Thresholds

In the context of the most demanding requirements, both "public interest" and "adequate" record revolves around data collection and analysis as related to NEPA threshold determinations. Under CEQ regulations, threshold determination looks at the context and intensity of actions that may have significant human environmental effects or actions likely to be highly controversial (58), highly uncertain or involve unique or unknown risks, or to control the course of future decisions, or to have significant cumulative effects. In addition to the normal agency missions, there are several major environmental issues that contain threshold tests (47 59):

> Endangered Species; Heritage Conservation; Coastal Management; Floodplains; Wetlands; Farmland Conversion; Recreation Resources; Critical Ecological Areas; National Wild and Scenic Rivers; National Trails; National Wilderness; Federal Permits; Air Pollution; Water Pollution; Hazardous Waste; Solid Waste; Drinking Water; Noise; Pesticides; and Energy Conservation.

The threshold is the crux of the monitoring problem. The environmental injury issue is focused on violation(s) of threshold(s) embedded in the purpose(s) of applicable legislation. The agency must be able to provide a reasonable explanation for its actions including a rational connection between the facts found and the choice made. Federal agencies have a duty to obtain important, significant, or essential information necessary to make a reasoned choice among alternatives. The key is reasonable effort; it does not require exorbitant costs or methods beyond the state of the art. (40 CFR 1502.22a).

However, anything less than a reasonable effort can be challenged as "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." (5 USCA 706.2A). The Court makes no decision; but it must engage in a "substantial inquiry" and "a thorough, probing, in-depth review." (91 S.Ct 823). "Substantial inquiry" requires a hard look to assure that agencies 1) abide by fair and reasonable procedures, 2) give good faith consideration to matters assigned to them, and 3) produce results that are defensible in reason. In particular, an agency is obligated to follow it's own policy including guidelines, Manual and Handbooks, interim directives, and memoranda if issued with authority. (701 F.Supp 1473). An agency also bears the "burden of refutation or explanation" as a continuing obligation to justify and explain its actions (486 F.2d 375).

Current experience suggests that the most effective data collection and analysis effort starts with the character of the threshold itself and on the prediction of future conditions relative to the threshold. From a practical standpoint, a vital step is to prioritize the effort toward controversial issues (58 60) and make sure that the Record of Decision contains clearly stated standards and suitable monitoring plans from which to measure compliance or show injury.

In so far as the Clean Water Act is concerned, it continues to set tough bench marks from which to measure the usefulness of water and related land resource monitoring. It has been tested and supported by the courts; it has a clear antidegradation threshold; and it has goals that are well defined thresholds for biological diversity, stability, and productivity. These planning and monitoring requirements are best exemplified by the CWA S404(b) guidelines at 40 CFR 230.

CWA S 319 on nonpoint source pollution control is not just another pretty face. The state controls the program, subject to EPA approval, which in turn is subject to Court sanction. The ultimate control then becomes CWA S 505 "Citizen Suits".

Sec 319 provides an exposed public forum in which an agency is evaluated for the water quality job being done. Existing case law is strong enough to insure agency financial responsibility and the legal dimensions against which performance is measured. Failure to budget for - and commit people - to the goals of the Clean Water Act brings up the question of who is going to manage the watersheds.

Regional Water Quality Program

The Clean Water Act has a watershed focus and includes a problem analyses of current trends, quantification of waterbody health, risk assessment of selected watersheds and activities, and a summary of watershed damage control programs and improvement actions to be taken. The State has the leverage to ask for any or all such information. It will be costly and disorganized not to include routine water quality reporting procedures into current planning operations. The regional water quality program focus is as follows:

<u>General Application</u> -

- stay off the impaired watershed list.
- fix watersheds that are currently on the list.
- fix unlisted watersheds that fail to meet Clean Water Act goals.
- meet S 404 exemption criteria: mandatory BMP's and no stream impairment.
- make monitoring efforts good enough for judicial use under Sec 505.
- concentrate monitoring efforts on advance warning systems.
- train/convince field people to immediately take care of small problems.
- routine measurement of ecosystem stability, diversity, and productivity.
- report results in terms of Stream Health.
- build data on selected reference reaches for regional application.
- regional leadership to develop and maintain planning and field tools.
- develop field screening techniques for routine Stream Health evaluations.

<u>Planning</u> -

- organize and manage ecosystems within the context of watersheds.
- anticipate pollution problems using a watershed cumulative effects focus.
- anticipate the scope of an enforcement program in the Record of Decision.
- focus prediction techniques on effects and functions from Table 1.2 that best support advance warning systems within the context of 40 CFR 230.
- continue development of watershed cumulative effects models.
- continue development of Stream Health evaluations.

<u>Implementation</u> -

- commit people and authority to stay on top of high risk activities including construction projects and special use permits.
- summarize the total Watershed Monitoring Program at least every 3 years.
- organize and train field people in simple field screen techniques.
- use evidentiary standard questions as basis for all monitoring efforts.
- routine evaluation of aquatic diversity and productivity.
- concentrate on attitude adjustment and training at field level.
- concentrate on eliminating personal levels of liability.

BMP	Best Management Practices
CEQ	Council on Environmental Quality; established by NEPA
CFR	Code of Federal Regulations
COE	Corps of Engineers, Dept of Army

Court citations (Volume and page; i.e. 731 F.Supp 970 (D.Colo 1989))

9 Cir	9th Circuit Court of Appeals
D.Colo	Colorado Federal District
F.2d	Federal Reporter, 2nd series
F.Supp	Federal Reporter, supplements
S.Ct	Federal Supreme Court Reporter

CWA	Clean Water Act, as amended, from 1948 to 1987.
EIS	Environmental Impact Statement.
EPA	U.S. Environmental Protection Agency.
ESA	Endangered Species Act
FLMPA	Federal Land Management Planning Act
FSM2500	Forest Service Manual, 2500 Section
NEPA	National Environmental Policy Act, 1969.
NFMA	National Forest Management Act, 1976.
OGC	Office of General Council
ONRW	Outstanding Natural Resource Waters
ROD	Record of Decision; required by NEPA
USC	U.S. Code
USCA	U.S. Code Annotated
USCC&AN	U.S.Code Congressional and Administrative News

NOTES

(Special thank you to Ann Hooker for additions to these notes)

1 CWA S 319 provides the state with authority to prepare comprehensive biennial assessments and watershed-by-watershed programs to take care of pollution problems. The states have requested federal agencies to help prepare watershed assessments and accomplishment reports; and may invoke EO 12372 (mandatory cooperation), if necessary to get it. (See FN 12 also).

2 Anderson & Gehrke 1989.

3 U.S. EPA 1985.

4 Anderson 1987.

5 Arjo 1990.

6 Braun 1986.

7 Coggins 1991.

8 Whitman 1989.

9 Federal case law has extensive watershed program implications. Citizens for Environmental Quality v. U.S. 731 F.Supp. 970 (D.Colo 1989) directs the Rio Grande National Forest to correct failure to specifically address Clean Water Act compliance as required by NFMA (36 CFR 219.23(d)). Requires inserting "and will comply with all applicable laws" into each Record of Decision.

The difficulty is that "programmatic" Forest Plans tend to identify the targets and outputs like road construction and timber production but leave real impact analysis until site-specific projects are proposed. Since the Clean Water Act <u>limits</u> the discretion allowed by NFMA, sometimes -- and with increasing frequency -- projects must be severely modified to correct for past damage, or prevent new damage, or allow time for stream health and water quality to improve enough to meet CWA and state requirements.

When resources available during the Forest planning stage are <u>not</u> used to make watershed and stream health condition surveys, the total burden shifts from the planning phase, where the trade-off between production targets and water quality issues are best addressed, to the project level. By then the land base has been analyzed for how best to operate, major planning costs have been incurred, and the proponent is WAITING for what the Forest Plan promised. In this setting, the failure to meet legal environmental requirements is very bad news, very disruptive to the administrative unit, and the messenger is in serious trouble.

10 U.S. EPA. 1983a. Biological health factors are listed on page 3-9 and relate to antidegradation and protection of existing aquatic uses. This is an important step because the guidance for these CWA S305 aquatic protection use attainability studies are issued officially under S304. Because they are "official", further use is immediately supportable in a legal context.

11 U.S.EPA. 1989.

12 Ohlander 1993a. Table B lists requirements incorporated by S319.

13 The purpose of an EIS is to avoid speculation of impacts by ensuring that available data are gathered and analyzed prior to project action; including the cumulative effects of past and future harvest activity leading to aquatic habitat degradation (843 F.2d @1195). Impacts to fisheries include sediment effects on fish food production, reproduction, lower fish populations, and adverse shade removal effects on trout (843 F.2d @1194; 753 F.2d @ 759).

14 Sidle & Hornbeck. 1991. Figure on p 271.

15 Lennahan 1985.

16 Pitt 1989.

17 U.S. Congress. annl.

18 NFMA 36 CFR 219.23(d & e); NFMA 36 CFR 219.27(a, b, c, e, f)

19 Anderson 1987 (pg 602, 604-05, 610, 614, 623) and Whitman 1989 (927-929) summarize from case law that compliance is measured against standards and

protection of uses, and not whether secondary measures like BMP's were correctly applied. States that fail to make management agencies comply, run the risk of losing funds or permit authority from EPA. And under CWA S 505, EPA can be forced to take such action as was done in Idaho (Complaint, Idaho Conservation League, #87-1326 D. Idaho) and in Colorado (Complaint, Environmental Defense Fund, #87-K-986 D. Colo).

20 CWA S 101(g) states policy that this act shall not interfere with state authority to allocate water under state law. "Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources."

However, Colorado's "The Basic Standards and Methodologies for Surface Waters", Sec. 3.1.3, states "No provisions of this Regulation shall be interpreted so as to supersede, abrogate, or impair rights to divert water and apply water to beneficial uses." totally defers to water rights. And since Colorado water law does not recognize instream flow as a "beneficial use", streams may be dried up regardless of water quality consequences.

The question of federal reserved water rights is a difficult one. The major issue is whether the NFs have in-stream water rights under the 1897 Organic Act purpose for "securing favorable conditions of water flows."

21 The authority to impose bypass flows on National Forest lands for habitat protection is based on Art. IV, S. 3 of the U.S. Constitution, the Organic Act which requires the Secretary to regulate use and occupancy of National Forest Systems lands, the Federal Land Policy and Management Act (FLPMA) which requires that each authorization contain terms and conditions which minimize damage to fish and wildlife habitat and otherwise protect the environment, and 36 CFR, Part 251, the FLPMA special-use regulations.

NFMA requires preparation of Forest Plans and requires that existing permits be revised as practicable to be made consistent with those Plans.

FSM 2541.35 requires Special Use permits to ensure that instream flows are in place for National Forest and for environmental needs. Permit does not confer any legal right to water use, nor does it provide a basis for acquiring such a right as against the United States (FSM 2782 & 2783.12).

The mandate for instream flow is supported by Federal case law.

a) Wyoming Wildlife Federation v. U.S., 792 F2d 981 (10th Cir. 1986) states that the Forest Service has an obligation to require instream flows that are consistent with FLPMA obligations and the project's EIS. (USFS had issued a permit without specifing any instream flow requirements). The Court said:

> "The stream flow requirements were clearly mandated by the Forest Service's own environmental impact statement, which states that the easement's stream flow levels are the minimum necessary to mitigate damage to wildlife habitat. It was not clear error for the district court to find that the Government's litigation position on this issue was not substantially justified when its position was in conflict with its own environmental impact statement."

b) Holy Cross Wilderness Fund v. Madigan, Peterson, Torrence, Marsh, et al. and City of Colorado Springs and City of Aurora. (10 Cir. 1992 Case 90-1252). USFS requires by-pass flows in streams being diverted, and also that flows be restored to streams that are dried up by diversion authorized by the Homestake I project and in a different watershed than the Homestake II diversions.

c) "Instream Flow Protection in the West", edited by McDonald, Rice, and Shupe. Natural Resources Law Center, University of Colorado School of Law, 1989. Chapter 4, "National Interest in Instream Flows."

22 Whitman 1989, page 958. Public reaction to water quality problems caused one Forest Supervisor to tell his entire staff that personnel would be

accountable for failure to implement planned BMP's. Typical actions available to the Supervisor include suspension-without-pay or termination of employment if the situation continues.

23 Generally a written contract is binding and employees can not bind the employer to terms separate from the contract. However, an employee that gives the impression of authority and does change the contract, puts the employer at risk and makes contract enforcement more difficult. Depending upon the situation, the employee may or may not be legally liability for damages arising from an unenforced contract, but he/she is most certainly subject to adverse personnel action including suspension or termination.

24 States may establish stricter standards than federal law requires; plans need to incorporate the toughest standards from all federal, state, and local agencies. Regardless, long term monitoring is still the tough one.

25 Pristine means natural processes are unimpaired; does not mean 'no use'.

26 Flinn & Reimers 1974. Criteria anticipates concerns in CWA S 301(b), 303, 405, and 504 for pollutant persistence, mobility, exposure, toxicity, severity, synergism, bioaccumulation, and endangerment to health.

27 Dunne & Leopold 1978.

28 Hynes 1970.

29 Kansas Biological Survey. 1985.

30 Karr & Schlosser 1977.

31 Odum 1971.

32 Whitton 1975.

33 Land use activities tend to affect physical processes first.

34 Antidegradation is here to stay. EPA's antidegradation policy cannot even be reviewed by the federal court of appeals because it is not reviewable under the Administrative Procedures Act. American Paper Institute, Inc. v. U.S. EPA, 890 F.2d 869 (7th Cir. 1989).

The general interpretation is that clean, very clean, and cleaned-up water cannot be polluted except in exceptional situations. The issue is eliminating "preventable causes" of pollution rather than merely aiming for standards. There is also no "de minimus" theory applicable to CWA violations and water quality standards are legally required to be met at all times (p631-2, Okla v. U.S.EPA, 908 F.2d 595 (10th Cir. 1990)).

For "Outstanding Natural Resource Waters" (ONRW), the antidegradation policy is violated with any human caused detectable change; not just those that violate numeric criteria. Setting a Designated Use gives additional protection beyond that conferred by the numeric criteria. In waters that allow for reduction in water quality, legal degradation requires that full implementation of BMP's and point source control must be in place first (p618, Okla v. U.S.EPA, 908 F.2d 595 (10th Cir. 1990).

35 State regulatory programs exist for chemical pollutant discharge but not for physical integrity. However, lack of a regulatory programs do not necessarily remove either the legal obligation or the standards embodied in the definitions of existing uses.

U.S.EPA. 1993. EPA Rgn 8 antidegradation guidelines includes impairment for non-water quality related impacts such as from "clean" sediment. If loss is expected, "no further activity" is among the control options (p26).

Antidegradation Review Worksheet (pg35-40) requires chemical, physical, or biological data sufficient to characterize the spatial and temporal variability of critical background factors likely to be affected by the proposed activity and the resulting water quality. If the point and non-point source controls have <u>not</u> been achieved, then the guidelines result in a preliminary decision of project denial (p23).

40 CFR 230.10(c) Finding of significant degradation shall be based on factual determinations, evaluations, and tests required by Subpart B and G,

after consideration of Subparts C through F, with special emphasis on the persistence and permanence of the effects on municipal water supplies, plankton, fish, shellfish, wildlife, and special aquatic sites; on life stages of aquatic life and other wildlife dependent on aquatic ecosystems; on aquatic ecosystem diversity, productivity, and stability; and may include loss of fish and wildlife habitat, or the loss of the capacity of a wetland to assiilate nutrients, purify water, ...

36 NFMA, 16 USC 1604(g)(3)(E)(iii), provides the "balancing test" that courts would use if an issue was raised. Note that Congress used the terms "water conditions" and "fish habitat", not just "water quality" or "fish". And the regulations at 36 CFR 219.27(e) clearly intend that water conditions include hydrogeomorphic and channel conditions.

However, the NFMA regulation does not define how bad it has to be before conditions and habitat are "seriously and adversly" affected. Since these activities are also subject to CWA S 404, the most demanding test is the "significant degradation" standards at 40 CFR 230.10(c).

NFMA also establishes criteria for:

- watersheds, flood plains, and wetlands (36 CFR 219.23(a,b,c,e,f));
- recreation features (36 CFR 219.21(a)(1) and -(g) off-road vehicles;
- fish and wildlife (36 CFR 219.19); and
- T & E species (36 CFR 219.19(a)(7).

37 NFMA 36 CFR 219.23 Water and soil resource (paraphrased) requires Forest Planning to provide (a) estimates of current water use, including instream flows; (b) identification of significant impoundments, transmission facilities, wells, and other developments; (c) estimates of the probable occurrence of various water volumes; (d) compliance with the Clean Water Act, Safe Drinking Water Act, state & local requirements; (e) evaluation of current and future watershed conditions that influence water yield, soil productivity, water pollution, or hazardous events; and (f) adoption of measures to minimize risk of flood loss, to restore and preserve flood plain values, and to protect wetlands.

NFMA quote: "... that an overall program of on-the-ground monitoring, coupled with research, insure the sound management of National Forest System lands. .... If research or evaluation establishes that a management system or method is producing impairment of the productivity of the land, such system or method will be modified or discontinued. [76 USCC&AN 6699].

38 CWA S 319 is only one element in complying with CWA. Also, CWA is only one of several federal laws that apply to watershed management. The Endangered Species Act constrains the discretion under NFMA; for water issues, 16 USC 1531 requires Federal agencies to cooperate with State and local agencies to resolve issues in concert with conservation of endangered species.

Further, federal agencies are governed as a matter of federal law by state water quality law and National Forest administration needs to keep tabs on the developing body of state administrative requirements including data requirements to feed into the state water quality planning programs.

It is critical that each National Forest use the state water pollution control plan, set of standards, maps showing designated uses, and abide by state regulations regarding NPDES permits.

39 U.S. EPA 1983b. Chp IV-2 diversity & community measures were explored.

40 Schwarz 1976.

41 U.S.EPA. 1983b. Para 2, pV-3, and Table V-2 are valid; new guidance (EPA 1990 Biological Criteria) fully supports the concept (p18&26). For USFS Rgn 2, stream health definitions were proposed to the combined hydrology, soils, fisheries, and ecology annual meetings in 1989, discussed in 1990, and voted as regional standard definitions in 1991.

The source of these definitions is the 1983 "Water Quality Standards Handbook" used by the states in developing water quality criteria and designated use classifications. Chapter 3 on water body assessments concludes with a series of case studies that use -- and review -- the types of assessments suggested by EPA. The participating states found the general techniques to be sound and useful for evaluating existing and potential uses; but requested EPA to further develop assessment guidance. The 1983 waterbody assessment manual -- and Table V-2 on biological health definitions was the result of this further inquiry and represents official EPA S304 guidance.

Page V-3 concludes that an internally consistent biological classification or yardstick is necessary for water body assessments -- which may later be referenced to the legally constituted use categories of the state.

EPA does not provide a productivity scale; however, the scale used is supported by Fig A10 (fish) and Table IV-2-8; and within parameters set by EPA's National program guidance for surface waters (EPA 1990, pg8-1).

42 OGC strongly suggests that persons likely to be witnesses take training on how to be an effective witness. Being prepared is essential, if the witness's testimony is to survive a grueling round of cross examination designed to destroy both factual information and credibility.

43 Benninghoff 1977.

44 Schuster & Zuuring 1986.

45 CWA S 209 includes a reference to Water Resource Council level B studies.

46 Colorado (Segmentation Criteria, Basic Standards and Methodologies, p. 9) is using "river basin and/or subbasin and specific water segments." See 3.1.11 and 3.1.16(2)(b) for standards and 3.1.7(1)(b)(iii).

47 Schmidt 1987.

48 NFMA 36 CFR 219.23(d) directs USFS planning to comply with CWA. Since water quality is an issue driven by the state, planners must use the CWA focus on basin (watershed and stream segment) planning as the authority for the size and description of accounting units. Visits with state personnel suggest that the use of FSM 2513 and 2541 watersheds is satisfactory.

FSM 2513.2 defines watershed size. Safe Drinking Water Act defines public water supplies (42 USC 300f) and critical protection areas for well heads (42 USC 300h-7) and special protection watersheds. FSM 2542 R2 supplement # 50 identifies municipal watersheds.

49 See also MacDonald, Smart, and Wissmar. 1991.

50 Ohlander 1993b. EPA is required by CWA S304 to issue official guidelines and information on the extent of pollution, pollutant mobility, and the effects on biological community diversity, productivity, and stability. These official publications are foundation to the S208 BMP process and, under case law, take on a mandatory nature (33 USCA 1314, note 5 & 6) until EPA formally modifies or rescinds them in the federal register.

S208 remains a statewide vehicle for water quality related planning that is not preempted by S319 unless agreement is reached to do so. S319 assessments are also statewide and may use information from 208, 304, or any other source that helps ... to identify streams that do not or will not meet the goals and requirements of the Act. S319 makes cooperation with S208 mandatory.

Given that BMP's are common ground between S208 and S319, it appears that any newly developed S319 BMPs would have to be as good, or better, than those approved under S208 -- and, presumably include satisfying the S304 guidelines referenced by S208. "Presumably" -- because the case law that make S304 mandatory is point source related, not nonpoint (33 USCA 1314, notes 5 & 6).

The relationship between S208 and S319 is important because the CWA S404 Exemption mandates the installation of state BMPs promulgated under S208. Again, presumably, this would also mean meeting both S208 and S319 BMPs (assuming no duplication) in waters declared to be impaired.

51 Navigable waters, aquatic environments, and aquatic ecosystems that serve as habitat for interrelated and interacting communities and populations of plants and animals are all "waters of the U.S.". This includes waters and their impoundments such as lakes, rivers, streams, intermittent streams, mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds; or their tributaries. (40 CFR 230.3(c&s) and CWA S 502(7)). This defintion applies to all federal lands and those used for public recreation, timber harvest, grazing, mining, or any situation where interstate commerce would apply (40 CFR 230.3(s)(1).

52 CWA S 404(f)(1)(F) defines the application of BMP's for any state approved program under CWA S 208(b)(4)(B) and (C); Subparagraph B collects (A) and consistency requirements in S 303. S 303(k)(1) provides for achieving water quality through implemetation of approved plans under S 208 and programs approved under S 319.

53 CWA S 404(f)(1) includes S 208(b)(4)(B)(iii) and 404(b)(1) guidelines at 40 CFR 230. 40 CFR 230.1(c) states that no dredge and fill be discharged unless it can be shown to have no adverse impacts. Discharges are prohibited if other, less damaging practical alternatives are available (40 CFR 230.10(a)). Significant effects are tested at 40 CFR 230.10(c). S 208(b)(4)(B)(iv) makes the activity subject to termination or modification for violation of any condition of the best management practice.

54 S 319(a)(1)(C) states the requirement to reduce levels of pollution to the maximum extent practicable. 40 CFR 230.3(q) defines practicable as "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes".

55 CWA S 404(f)(1)(E) defines protection requirements for roads using the standard of "no impairment" to chemical and biological characteristics; and to minimize individual and cumulative impacts. Procedures and tests to demonstrate compliance or non-compliance are found at 40 CFR 230.10(c).

Construct and maintain permanent or temporary roads and skid trails in accordance with mandatory BMPs to assure that flow & circulation patterns and chemical & biological characteristics of U.S. waters are not impaired, that the reach is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. (33 CFR 323.4(a)(6) paraphrased).

Federal agencies are subject to S 404 including enforcement [(CWA S 404(s)(1) & (3)); S 404(n); (S 309(a)(1) & (c)); (33 CFR 323.3(b) & 326]. The COE's jurisdiction is to the outer limits of ordinary high water mark, associated, or adjacent wetlands (33 CFR 328.1, 328.4(c)). (Ordinary high water mark is established by water fluctuations and indicated by physical characteristics such as a clear, natural line impressed on the bank, no terrestrial vegetation, or similar indicators (33 CFR 328.3(e)).

Silviculture exemption at CWA S 404(f)(1)(A) does not include road construction [33 CFR 323.4(a)(1)(iii)(B)]. Roads, including temporary roads and skid trails, must meet requirements at 33 CFR 323.4(a)(6) in order to claim exemption from the S 404 permit process.

Mandatory road and trail BMPs require baseline provisions: (COE 33 CFR 323.4(a)(6)) including: limit road & trail system to the minimum feasible number, width, and total length consistent with specific operations, topography, and climate; all roads and trails (*/) shall be located sufficiently far from streams or other water bodies (except for portions which must cross) to minimize discharges; crossings shall be bridged, culverted, or otherwise designed to prevent the restriction of expected floods flows; fills shall be properly stabilized and maintained during and following construction to prevent erosion; minimize heavy equipment impacts and vegetative disturbance in "waters" outside construction zone; avoid discharges into ... special aquatic sites (includes riffles and pools); ...

*/ "and trails" is not part of the COE regs, but included from S208 where FS timber sale contract provision (B6.5c) prohibits wheeled and track-laying equipment use in streamcourses that have defined or scoured channels, that show evidence of developing sufficient head of water to move debris or erode the channel, or which may develop such characteristics if diverted or blocked by logging activities (USEPA 1973 pg 55-59).

56 CWA S 313(a) requires federal agencies engaged in activities that may result in the discharge or runoff of pollutants to comply with state water quality standards. However, some states only apply their standards to point sources which leaves the non-point sources outside of state regulation. As a result, several lawsuits have been brought in federal court to make state standards mandatory on federal agencies even if the state has no regulatory program.

CWA S 404(b)(1) guidelines (40 CFR 230.10) are also important in NEPA analysis because "impairment" can be shown under federal criteria without needing to show violations under state law. This avoids the problem that "if EPA has approved a state's water quality standard, and there is no violation of state law, how can there be an impact under NEPA?"

CWA S 208(b)(4)(A) incorporates S 303 which requires meeting state water quality standards. The Forest Service argued that BMP's take the place of state water quality standards and, therefore, if BMPs are implemented to the satisfaction of the state, then the water quality standards are not binding on land use activities. This was rejected by the 9th Circuit Court (Northwest Indian Cemetery Protective Association v. Peterson, 764 F.2d 581 (9th Cir. 1985); 795 F.2d 688 (9th Cir 1986). Aka "G-O Road").

The Court ruled that the Forest Service had to meet state water quality standards promulgated under S 208. Since CWA S 303(k)(1) links S 319 to S 404(f)(1)(F), presumably S 319 (which came after 1986) would be covered.

The substance of the 9th Circuit Court is also found in the 404(b)(1) guidelines issued by EPA (40 CFR 230). Among other things, 40 CFR 230.10(b) prohibits discharge if it causes or contributes to violation of state water quality standards.

57 NFMA 36 CFR 219.12(k) requires evaluation of how well the objectives are being met; requires documentation of effects, including significant changes in productivity of the land.

NFMA 36 CFR 219.27 provides authority to protect and monitor changes in the physical conditions of streams. The USFS must comply with 36 CFR 219.27 to implement NFMA, regardless of state programs under CWA S 319.

58 "Controversial" refers to substantial dispute as to the size, nature, or effect of the action rather than to just the opposition to a use (843 F.2d 1190, @1193 referring to 681 F.2d @1182, 484 F.2d 158). The challenge is to the methods, data, analysis, and resulting conclusions.

59 In addition to state standards, federal agencies must also respond to stream segments constrained by aquatic or terrestrial species covered by the Endangered Species Act. The necessary monitoring will need to be tailored to a particular watershed/basin in a particular state and for a particular "class" of activity such as logging.

60 Bevenger 1991.

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CLEAN WATER ACT - MONITORING AND EVALUATION

Part 2. Watershed Reporting

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CLEAN WATER ACT - MONITORING AND EVALUATION

Part 2. Watershed Reporting

Objectives that require a watershed level of analysis are repeated below:

- stay off the impaired watershed list.
- fix watersheds that are currently on the list.
- fix unlisted watersheds that fail to meet Clean Water Act goals.
- report results in terms of Stream Health.
- organize around existing National Forest watersheds and subwatersheds.
- anticipate pollution problems using a watershed cumulative effects focus.
- anticipate the scope of an enforcement program in the Record of Decision.
- summarize Forest-wide Watershed Monitoring Program at least every 3 years.

The Clean Water Act and watershed cumulative effects analyses requires an accounting based on watershed condition and on specific measures such as damage to fisheries and reduction of aquatic habitat (1 2 3 4 5 6 7 8 9 10 11 12).

National Forest planners face legal mandates that blend ecological and economic objectives. For the ecological framework, Eugene Odum suggests that when it comes to human ecology, the minimum ecosystem unit is "... the whole drainage basin or watershed that includes terrestrial and aquatic systems together with man and his artifacts all functioning as a system." (13). Such natural system functioning is neutral to human well-being; management either supports stability or creates instability and destruction. History shows that "...abysmal ignorance of what it takes to run a balanced ecosystem..." favors destruction (14 15).

The Forest Service has been soundly criticized by Senator Patrick Leahy. He believes that National Forest management is in fact not meeting environmental mandates and "suggested" a change to re-affirm responsibility and leadership, and to seek public trust and credibility (16). The Forest Service responded with "New Perspectives", defined as ecological and economic sustainability based on land stewardship and long-term health, diversity, and productivity (17).

The linkage between "New Perspectives" and land management is still the NEPA process and the Record of Decision. The burden of getting the job done, including mitigation and monitoring, is still the responsibility of the approving agency. But, there have been numerous failures.

With regard to the Clean Water Act, the Environmental Law Institute reports the general perception that the job is not getting done; that an attitude adjustment and learning experience on the part of polluters is necessary to insure treating water quality standards as seriously as the Internal Revenue Service tax code. Section 505 Citizen' lawsuits, filed directly against polluters in federal court, are on the rise and showing substantial success. These S.505 citizen lawsuits bypass state and federal regulators; industries fear that as citizen suit's gather momentum, it will upset the balance of power in normal negotiations with state and federal regulators over pollution standards (18).

The conclusion here is not that Forest Service activities are subject to S.505 lawsuit's or challenge under the Administrative Practices Act; but, that accountability is now a watch word like it has never been before.

The BIG BUCKET and the little dipper Analog

A major road block to attaining and maintaining an adequate accounting system for watershed and stream health conditions is the tremendous number of ways in which it can be done. From the evaluation standpoint, the literature is nearly afloat with analytical processes and procedures that get at various parts of the problem. But there is not much systematic or comprehensive analyses that deals with the totality of watershed conditions -- it is sort of like drilling for oil with a 1000 holes, each of which is 10 feet deep.

Current experience suggests that the lack of a comprehensive approach is mainly the result of insufficient commitment to get the job done and keep up with the detail. However, the problem is also due to the perspective at which watersheds are viewed. For example, planning questions that center around the economics of water yield and geomorphic equilibria favor a BIG BUCKET analysis with little or no analysis of distributed effects. This approach lends itself to the display of gross effects, thresholds of concern, and a variety of watershed screening criteria that do not require site specific information.

There is a secondary level of analysis that involves the distribution of effects in both time and space; it is the "dipper" in the BIG BUCKET analog. A typical dipper frame of reference would be sites that fail to meet stewardship levels of soil and water protection. Often such sites become severely damaged before they are treated and BIG BUCKET effects are largely ignored because program control and the budget process tends to shift treatment randomly from watershed to watershed fixing a few acres here and there.

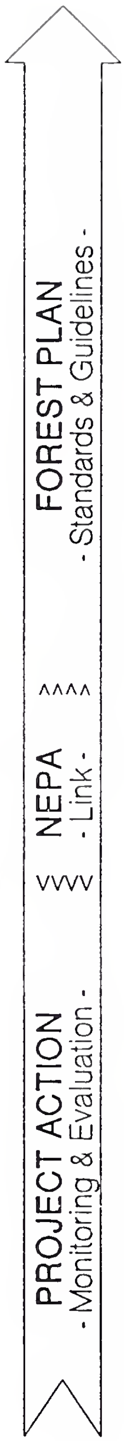
In summary, the dippers and the BIG BUCKETS are separated; just as there is no accounting system to formally link watershed condition, site recovery, and stream health together. It should be obvious that both levels of analysis are needed in the same loop; that the mandates for land productivity and stream health protection are entwined with NEPA cumulative effects analysis and State water quality reporting requirements; and that the sum total reflect a tough legal framework that actively joins the BIG BUCKET and the dipper. Said another way: To do or not to do is not the question; the question is "how".

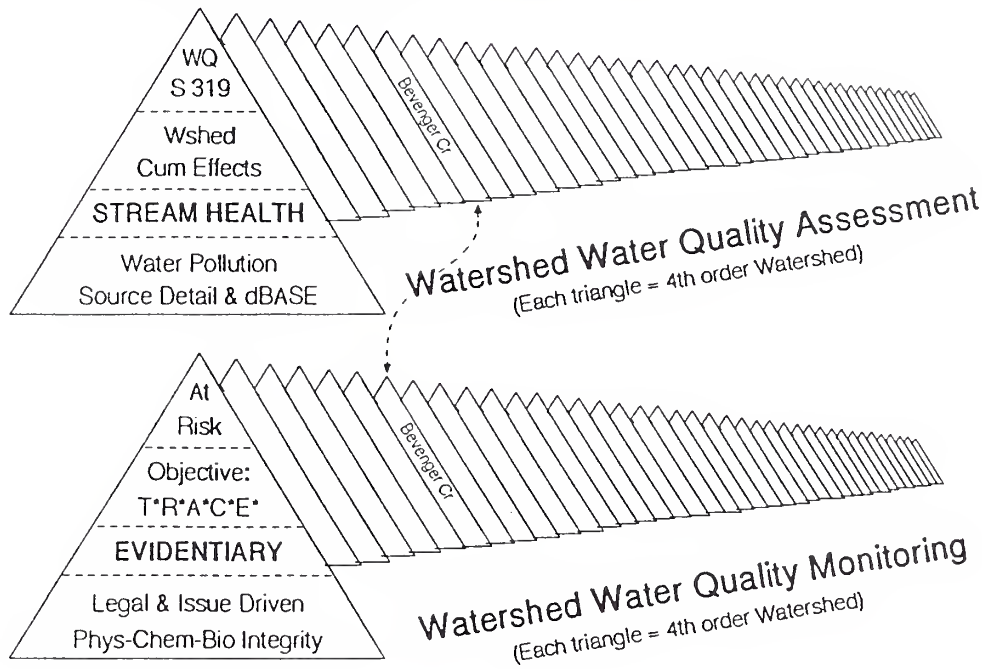
Watershed Information

Figure 2.1 "Watershed Information Schematic" suggests a general view of how the various levels of watershed evaluation and accounting might fit together. The arrow reflects the time continuum -- planning sets standards and guidelines; project monitoring and evaluation then help refine planning standards and guidelines. Forest Plans include watershed assessment and monitoring plans (4 19). When project areas are selected, standards and guidelines help structure project alternatives. Project level watershed and stream health surveys furnish a basis for determining the cumulative effects of alternatives. Vulnerable sites and stream reaches are identified as candidates for monitoring and mitigation planning. The Record Of Decision becomes the contract with the public.

Part 2 concentrates on accounting for watershed assessment and the necessary monitoring. The Watershed Water Quality Assessment summarizes land management and estimates of stream health. From this base, watershed cumulative effects and information for the State's biennial CWA S 319 Water Quality Report can be derived. The NEPA link and project action are discussed briefly.

Watershed Information Schematic





PROJECT AREA SELECTION

-- Alternatives: Results & Risks

STREAM HEALTH SURVEY

-- Confirmation of Condition & Miles

-- Prediction of Effects by Alternative

SELECTION OF VULNERABLE SITES

-- Select Reference Locations (T-Standards)

-- Stream Reach Characterization (T-Class)

RECORD OF DECISION: Mitigation & Enforcement

-- Implement Monitoring at Selected Sites as planned

-- If **T-Walk** is included, then plan visits: Storm Runoff Control, T-Depth, Tarzwell Substrate Ratio & Diversity Screen

Decker Wash Planning Area

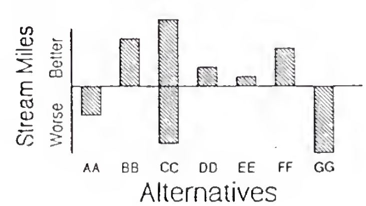


Figure 2.1 Watershed Information Schematic

Watershed Information Schematic - Figure 2.1 Narrative -

PROJECT ACTION - FOREST PLAN ARROW.

As the planning-evaluation-standards-planning cycle repeats, responsibility to "waters of the United States" continues to be a crucible test of management.

FOREST PLAN - Standards and Guidelines.

Failure to comply with local, State, and Federal law and regulation creates liability. The assessment and monitoring for compliance to the Clean Water Act is a demanding task. When requirements from legislative history, the CWA S 319 report, watershed cumulative effects under CEQ regulations, and Federal case law are listed together, the result is a comprehensive list of parameters that define the watershed assessment problem.

The Assessment has 4 major levels: pollution sources, stream health, watershed cumulative effects, and biennial Statewide Water Quality Report.

- The foundation is a Water Pollution Source Survey with detail about activities and land conditions that are, or may be, "At-Risk".
- A Stream Health summary of stream miles by health classes is developed from pollution source data and the expected effect on stream health.
- Watershed Cumulative Effects is driven by stream miles that change from one health class to another as a result of the alternative.
- The biennial Water Quality S 319 report is defined by the Clean Water Act.

Monitoring has 4 major levels: monitoring parameters, evidentiary standards, type of monitoring, and "At-Risk" determinations.

- Parameters are based on federal case law and legislative history.
- Test data and analyses to ensure that evidentiary standards will be met.
- Specify type of monitoring and clarify the objectives for the effort.
- Determine streams that are, or could be, "At-Risk".

The NEPA link.

Proposed project action is planned using the NEPA process. Stream health and watershed condition influence the choice of project area and alternatives. Adequate protection may require prerequisite or extraordinary mitigation, no surface occupancy, postponement, or even to exclude certain activities.

PROJECT ACTION - monitoring and evaluation.

The Stream Health Survey determines (or confirms) the miles assigned to each health class. From this, watershed cumulative effects can be displayed for each alternative as shown by the "Decker Wash Planning Area" graph.

Monitoring Vulnerable Sites helps improve the effort to catch small problems before they become large and costly. Stream health conditions before the project establish the antidegradation level to which the project must comply. Systematic measurements including all aspects of channel material and channel physics are necessary to document changes. If the site has not been impacted, then it may also be used as a Reference for extrapolation to similar streams.

The Record of Decision implements the alternative including mitigation and monitoring; it is a legal contract with the public.

In the discussion under "Part 1. Legal Framework", the need for watershed level data and analysis was described: first, federal agencies are directed to assist the States in preparing the biennial Statewide Water Quality Assessment (CWA S 319 report (20 21)); and second, federal agencies must meet analysis requirements imposed by the National Environmental Policy Act (1 3 4 22 23 24).

Also in Part 1, key water quality impacts, the temporary nature of acceptable environmental changes, antidegradation, and watershed geomorphic equilibrium were jointly developed as the basis for watershed cumulative effects analysis with major arguments presented as follows (25):

- That compiling the most demanding set of planning requirements starts with the legislative history and subsequent confirmation through case law. Table 1.1 "Water Quality Impacts" was offered as a statement of that minimum foundation level for watershed cumulative effects analysis.

- That the monitoring and evaluation problem is with long term ecological effects generated mainly by changes in sediment regimes, changes in temperature regimes, changes in oxygen and oxidation regimes, metal contamination within basic life processes, poisoning of community members, changes in watershed geomorphic equilibrium, and changes in dissolved chemical regimes (26).

- That a measure called 'Stream Health' is useful as an integrated definition of several specific biological parameters including eutrophication; key species; and aquatic ecosystem stability, diversity, and productivity.

The expectation is that <u>if</u> the same procedures and definitions are used for both the CWA S 319 water quality reports and watershed analyses, then planning would be simplified and less expensive. Like the S 319 report, a watershed cumulative effects analysis requires a watershed focus, a problem analyses of current trends, a quantification of waterbody health, an evaluation of damage control and restoration programs, and a risk assessment of areas and activities (20 27).

Stream Health

> "The Committee wants to know what waters are in their natural state and where they are located. The Committee wants to know what waters are of the quality which will assure protection and propagation of fish, shellfish, and wildlife. .... The Committee wants information on those waters which fail to meet high quality requirements, where they are located, and the reason for the failure." [3722 USCC&AN 1972].

This quote is the bread and butter of the Watershed Water Quality Assessment and Monitoring efforts. The overriding objectives are to reduce vulnerability to personal liability and litigation, reduce losses to the resource base, reduce restoration costs, and reduce loss of future management options.

The descriptive names for Stream Health Class were chosen carefully: first, to be complimentary to similar concepts in other resource disciplines; second, to serve as a scale of management impacts on stream conditions; and third, to use nomenclature that carries a quickly understood value judgement. The term "resource use" means the interaction of human use with natural impacts including

drought, wind, insects, disease, fires, floods, and land slides. There is no special category for these natural events because both planning and policy related to natural resource use has been around long enough to incorporate the risk as well as the magnitude of such events.

Below is a brief description of the transition among Stream Health Classes as it relates to management options:

Robust Stream Health suggests that no resource use changes are required; that all systems are in balance; and that natural processes are effectively assimilating management generated effects.

Adequate Stream Health suggests that the resource damage is lawful and within the permitted conditions; that only a few areas are lost to production.

Diminished Stream Health suggests that natural systems are stressed in ways that require resource use to back-off before major damage is done.

Impaired Stream Health suggests that natural systems are clearly pushed too hard; that damage is substantial and recovery will be slow.

Precarious Stream Health suggests that natural systems have been pushed to the limit; that recovery will be very slow and expensive.

Catastrophic Stream Health suggests that natural systems have been pushed beyond their limits and the existing site quality has been destroyed. The management phase is now concerned with failure and liability with substantial resources going to on- and off-site damage control.

Since the Clean Water Act is an accountable managerial function, the assessment of Stream Health is a key item and reflects a 'bottom-line' measure of how current conditions stack up against the legal goal of ecological integrity. The technical job is to evaluate the existing and future Stream Health Class based on definitions of ecosystem stability, diversity, and production.

Watershed Cumulative Effects

During the last round of planning under the National Forest Management Act, EPA reviewed dozens of Forest Land Management Plans and associated EIS's. Their formal responses contained both procedural material and detailed comments about all aspects of resource management that create environmental impacts.

One central issue concerned the lack of detail about water quality monitoring and compliance with State and Federal statutes, including those relating to watershed cumulative effects. To reduce the rock throwing, EPA's comments for the years 1984 to 1987, and pertinent case law were reviewed for specifics that could be used as a framework for analysis. Draft material was discussed with staff specialists from EPA and State water quality agencies, then redrafted. The results are compatible with the region's water quality program and approach to watershed assessment (25 28 29).

The Clean Water Act makes a good and legally supportable foundation for watershed cumulative effects analysis as discussed in Part 1. The concepts necessary to make the translation from the Clean Water Act to a suitable NEPA

analysis are already in place and well supported by the regulations; the concepts are summarized as follows:

a Watershed cumulative effects equates to prediction of future effects as measured through the antidegradation provision of the Clean Water Act and includes all beneficial aspects of watershed hydrologic functioning and land productivity.

b Cumulative effects are those conditions that do not allow maintenance of ecological integrity. Maintenance of ecological integrity requires that any changes ... be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original. [3742 USCC&AN 1972].

c Geomorphic equilibrium between sediment transport and stream power is a necessary and major condition of physical integrity as defined by the Clean Water Act. Therefore; upsets in equilibrium for whatever reason create cumulative effects as defined in the NEPA context.

d A stream channel has an upper level of tolerance to changes in the geomorphic processes. Channel cutting or filling, stream bank erosion, increased rates of mass wasting, and a shift toward wider or shallower channels are indicators of exceeding a geomorphic response threshold (30 31). These constitute long term adverse cumulative effects.

e For a selected hydrologic event, the risk of upsetting geomorphic equilibrium and initiating adverse watershed cumulative effects is greatly increased as watershed disturbance approaches some upper limit.

f Stream channels are part of the land and managed under legislation that includes securing 'favorable conditions of water flows'. Changes in this 'favorable condition' is by definition 'significant'; it can not be made 'insignificant' in order to avoid the necessary mitigation.

Watershed assessments require information that is not routinely displayed. And since a part of it is of the 'dirty laundry' variety, there is often reluctance to make the effort; first, because the expense that can not be easily charged off to short-term targets and second, the increased scrutiny may turn up problems that will dictate a change in operations or production targets.

However, if land stewardship is a genuine goal, then the least costly approach is to neutralize the politics, fix the problems, upgrade management to eliminate any further resource damage, and follow through with accomplishment reports.

The Watershed Water Quality Assessment table (Fig 2.2 & 2.3) is offered as a basic watershed condition summary to support both CWA S 319 water quality reports and cumulative effects analysis. The assessment contains a broad list of quantified pollution sources, the results from damage control and restoration efforts, and what remains at risk. The assessment, together with descriptions of damage control programs and improvement projects, furnishes a starting point for additional monitoring, for corrective action, and for the "pre-project" conditions from which to base an cumulative effects analysis of the proposed alternative(s) (5 6 32). In all cases, the results or predictions are tabulated using a standard set of definitions for Stream Health categories (25).

WATERSHED WATER QUALITY ASSESSMENT - Summary

Date:__________________

WRC Cat #: NFS Wshed #: Watershed:

Natl For: District: Progm Officer:

Management situation:

Stream Health Watershed Summary (class, stream miles, comments)

	Total miles	NFS miles	Project Status (monitoring or restoration plans)
Robust	: mi	mi	
Adequate	: mi	mi	
Diminished	: mi	mi	
Impaired	: mi	mi	
Precarious	: mi	mi	
Catastrophic	: mi	mi	

Watershed Summary - Water Pollution Sources

Land & Water Operations	unit	Total Quantity	National Forest System Lands Quantity	Safeguards	At-Risk
Geophysical Modification					
Agriculture	ac				
Corridors	mi				
Deforestation	ac				
Heavy use sites	ac				
High hazard lands	ac				
Mining, milling, & mfg sites	ac				
Roads & trails	mi				
Silviculture	ac				
Water collection/transfer	mi				
Water storage surface	ac				
Wetlands & Riparian altered	ac				
Chemical Contamination					
Bulk transport routes	mi				
Energy production sites	ea				
Land use application	ac				
Natural non-point	ac				
Point sources	ea				
Residue disposal - tox/haz/rad	ea				
Solid waste landfill	ea				
Tailings & spoil banks	ac				

Figure 2.2 Watershed Water Quality Assessment - Summary

WATERSHED WATER QUALITY ASSESSMENT

The summary of water pollution sources displays activities at-risk, a starting point for monitoring and corrective action, and "pre-project" conditions for watershed cumulative effects analysis. The results are summarized by Stream Health by miles of perennial streams. There are 2 forms: summary and detail.

Date. Month and year is enough.

WRC Cat #. WATER RESOURCE COUNCIL Cataloging Unit is used to help States summarize water body health conditions through state reporting systems. The Forest Service also uses it in reporting fire control efforts, water resource data, and it has been included in the planning data bases.

NFS Wshed #. NATIONAL FOREST/GRASSLAND WATERSHED FSM Codes have been in use since 1965.
Watershed. Use the name as found in the FS manual.

Natl For. & District. National Forest/Grassland and District administrative unit names allow normal follow-up for questions and program coordination. If a watershed is located on more than one District, each District reports just that portion for which it has administrative responsibility.
Program Officer. On each District, someone has managerial responsibility for the watershed program and serves as a contact for questions and day-to-day operations.

Management Situation. This provides a general aspect for the area and any activity or condition that needs to be singled out: impacts generated by existing land use conditions; drought induced ecological chanages; emergency fire or flood conditions; extensive highway construction; or new land use plans.

Stream Health Watershed Summary. In this summary, all bits and pieces of information are stirred togther for the watershed and Stream Health is interpretated. Think specifically and assign each and every mile of the stream to one of the classes. The Total mile accounts for all streams in the system; the NFS miles just account for streams under NFS responsibility. Count miles of normally expected perennial streams; build agreement with fisheries reports on miles. Use map scale of 1:24000.

The goal is to have all stream miles in the Robust and Adequate Health Classes. The difference between "pre-project" and "project" can be used to identify components that help tie monitoring and restoration plans into a comprehensive effort to bring water quality up to the necessary standards.

Watershed Summary - Water Pollution Sources. Tabulation from Watershed Detail - Water Pollution Sources.
Land & Water Operations. List of major activities frequently associated with water pollution.
unit. area, linear, & individuals; unit applies to all cross columns.
Total Quantity. Tabulation from Watershed Detail tables; based on Map scale 1:24000 or field reports.

National Forest System Lands. Tabulate for that part for which National Forest System has jurisdication.
Quantity. NFS responsibility only.
Safeguards. Sites are protected and all aspects of the CWA are complied with. May include protection by soil and water conservation practices, permanent vegetative buffers, proper landing location, riparian fencing, expedient sediment traps, chemical treatment plants, or dam flow regulation. May also include aggressive administration, inspection, contract enforcement, and corrective action.
At-Risk. Sites that are not fully protected. Water quality impacts that exist from current activities, or where response times can not be met under emergency conditions, or administrative resources are not adequate to stay on top of high risk situatuions, or erosion control efforts are lax - are all examples of sites and management situations that are at-risk.

Extra items from the Watershed Detail - Water Pollution Sources

Unit & tag. Area, length, or individual count. Use the [ ] to tag which items refer to the site. For example, you might list 4 separate gold mines in an area that are all "abandoned metallic sites".
Site Identification & Location. Essential to have an exact name and location for each and every source. If you think in terms of specifics, then the information collected for each site can be used to build better plans and accomplishment reports. The location of "At-Risk" sites that are fixed contribute to better downstream Stream Health and serve as a basis of documenting improved miles carried foreward to the summary. Administratively, it is easier to make updates from specific site information.

 Date: ______________

WRC Cat #: NFS Wshed #: Watershed:

Land & Water Operations	unit & tag	Watershed Totals: All Ownrs	Natl For Sys: Safegrd	Natl For Sys: At-risk	Site Identification and Location
GEOPHYSICAL MODIFICATION					
Agriculture	ac				
Irrigated crops	[ ]				
Dryland crops	[ ]				
Fragile rangelds, poor condtn	[ ]				
Durable rangelds, poor condtn	[ ]				
Corridors	mi				
Buried pipelines	[ ]				
Canals & ditches	[ ]				
Deforestation	ac				
Forest to burn	[ ]				
Forest to grass	[ ]				
Brush to grass	[ ]				
Vegetation to non-vegetation	[ ]				
Heavy use sites	ac				
Outdoor recreation	[ ]				
Residential/business	[ ]				
Rural subdivision	[ ]				
High hazard lands	ac				
Chronic wind erosion	[ ]				
Severe O.M. & nutrient loss	[ ]				
Mass failure: active	[ ]				
"High" hazard potential	[ ]				
"Moderate" hazard potential	[ ]				
Gullies & severe sheet erosn	[ ]				
Mining, milling, & mfg sites	ac				
Active metallic sites	[ ]				
" non-metallic sites	[ ]				
Abandoned metallic sites	[ ]				
" non-metallic sites	[ ]				
Roads & trails	mi				
Asphalt roads	[ ]				
Aggregate roads	[ ]				
Graded (ditch; no aggregate)	[ ]				
Waterbar & cutslope	[ ]				
Temporary roads	[ ]				
Off-road trails	[ ]				
Primitive (no maintenance)	[ ]				
Silviculture	ac				
Regen, new cut, no recovery	[ ]				
Regen, < 1/4 hydrlc recovery	[ ]				
Regen, 1/4 to <1/2 h.recvry	[ ]				
Regen, 1/2 to <3/4 h.recrvy	[ ]				
Regen, 3/4 & > hydrl.recvry	[ ]				
Salvage operations	[ ]				
Non-regenerated	[ ]				
Water collection/transfer	mi				
Stream flow decreased	[ ]				
Stream flow increased	[ ]				
Historic channel "drives"	[ ]				
Historic flood effects	[ ]				
Operations, spills, & flush	[ ]				
Channelized/straightened	[ ]				

Figure 2.3 Watershed Detail - Water Pollution Sources

Watershed Detail - Water Pollution Sources (p 2) Watershed:

Land & Water Operations	unit&tag	Total	Sfgrd-NFS-	AtRisk	Site Identification and Location
Water storage surface	ac				
Natural lakes & ponds	[ ]				
Stockponds	[ ]				
Impound w/ permanent wtr level	[ ]				
" w/ seasonal drawdown	[ ]				
" w/ rapid fluctuations	[ ]				
Wetlands & Riparian altered	ac				
Water level lowered	[ ]				
High water table induced	[ ]				
Sites filled or drained	[ ]				
Tree cover reduced/removed	[ ]				
Brush cover reduced/removed	[ ]				
Soil infiltration reduced	[ ]				
CHEMICAL CONTAMINATION					
Bulk trnspt (haz/tox) routes	mi				
Highway	[ ]				
Pipeline	[ ]				
Railroad	[ ]				
Energy production sites	ea				
Oil & gas wells	[ ]				
Abandoned well sites	[ ]				
Coal & lignite mines	[ ]				
Geothermal & oil shale	[ ]				
Hydroelectric	[ ]				
Land use application	ac				
Aerial spraying	[ ]				
Ground spraying	[ ]				
Slow release pellets	[ ]				
Residual persistent biocides	[ ]				
Natural non-point	ac				
Saline leach & erosion areas	[ ]				
Mineralized seeps & springs	[ ]				
Erosion of mineral deposits	[ ]				
Point sources	ea				
Chemical discharge/fumes	[ ]				
Burning/exhaust fumes	[ ]				
Mine tunnel/adit drainage	[ ]				
Haz/toxic chemical mixing site	[ ]				
Residue disposl -tox/haz/rad	ea				
Container disposal site	[ ]				
Accidental spills & clean-up	[ ]				
Pollution control sludges	[ ]				
Metal mine/mill sludges	[ ]				
Solid waste landfill	ea				
Unregulated dumping	[ ]				
Residential/business	[ ]				
Industrial/Agricultural wastes	[ ]				
M & I treatment sludge	[ ]				
Waste oil & spill disposal	[ ]				
Abandoned dumps	[ ]				
Tailings & spoil banks	ac				
Coal/spent shale	[ ]				
Dredge/strip mine	[ ]				
Radioactive sites	[ ]				
Mineral mine & mine tailings	[ ]				

Storm Runoff

In the context of watershed cumulative effects, storm water analysis is directed by 1) recent publication of EPA's storm water regulations, 2) as a mandate from the Clean Water Act's legislative history, and 3) from the perspective that storm runoff control is a major feature in all aspects of pollution abatement. State storm water regulations, including design storm criteria, apply to any National Forest activity for which a National Pollution Discharge Elimination System (NPDES) permit is required (33 34 Appendix A).

Although there are differences among states, the 10-year, 24-hour rain storm (or snowmelt equivalent) is a commonly used statistic for storm water NPDES permit requirements (35). Thus, it was chosen to be the basis of storm runoff analysis and as a dividing line between those activities that are "safeguarded" and those that are "at-risk" (as on the Watershed Water Quality Assessment). The 10-year, 24-hour storm has a 10% chance of occurring in any given year, and a 65% chance of occurring at least once in the next 10 years (36).

The problem in estimating storm runoff is compounded by the fact that not many watersheds are adequately gaged for such information. The analysis must then proceed from known watershed responses and a comparison of factors including soils, vegetation, and land use. However, conducting such analyses on National Forests is a challenge because of the sheer size and complexity of the geologic and hydrologic conditions; and there is a lack of information about geomorphic equilibrium, watershed condition, and stream health (37).

Because the primary effect from land use is the increase in storm runoff volume and peak flow rates, current experience suggests that surveys focus on areas and activities with the highest runoff potential. This approach is used as a follow up to the Watershed Water Quality Assessment discussed before.

After a review of water resource models and computations, the SCS Runoff Curve Number method is a good and practical solution for the range of National Forest watershed hydrologic conditions and most able to meet the evidentiary standards discussed in Part 1 Legal Framework (38 39). The following provides background on elements of the SCS Runoff Curve Number method that make it useful for watershed cumulative effects and storm water analysis.

<u>Runoff Curve Numbers</u>. Following the passage of the 1954 Watershed Protection and Flood Prevention Act (PL 83-566), the Soil Conservation Service, as lead agency and in cooperation with the Agricultural Research Service and Forest Service, developed a family of hydrologic methods and field techniques that could be used in small and ungaged rural watersheds. These methods rely heavily on extensive soil and water conservation studies carried out nationwide during the 1930's, 40's, and 50's; and involved some 10,000 plot-years of data from several agencies including the Forest Service (40). The methods and rationale are currently used by numerous local, state, and federal agencies involved with dam safety, non-point source pollution, and storm water control (34 41).

Storm runoff volume, peak flow, and runoff distribution vary with climate, rainfall characteristics, vegetation, soils, watershed size and shape, land use, topography, and hydrologic properties of soil-cover complexes (42). Vegetative cover and litter protect the soil and provide organics that promote loose and friable soil structure. Therefore, land use practices or natural events (i.e. fire) that remove major amounts of vegetation, or accelerates the loss or

oxidation of litter and humus, or creates excessive soil compaction, often drastically reduces infiltration rates and surface depression storage. Total storm volume and peak rates will increase to the extent that infiltration is the limiting factor and overland flow the dominant storm flow runoff process.

The Forest Service has made numerous hydrologic studies for forest and range conditions in both humid and dry climates (43). In humid forest types, litter protects humus from rapid decay and provides the source material for humus development. Humus depth increases with age of the stand until an equilibrium is reached. Depths of 12" are not uncommon, but 6" is about average for old and protected forest sites. Forests on unstable soils or those with a history of relatively frequent fires develop much less than 6" of humus with, perhaps, 3" being a realistic goal for long term forestry.

Under dry climatic conditions, humus does not accumulate to any great extent. For these forest-range types, soil group, cover type, land use, and cover density (including litter) are the controlling variables for infiltration.

The runoff curve number rationale operates at the precise level of detail needed for determining land use effects on ground cover, compaction, litter, humus; and consequently, on storm runoff. Runoff curve numbers are assigned to soil-cover complexes on the basis of their hydrological response to storm rainfall:

Soils. The hydrologic properties of soils are classified into one of four major hydrologic soil groups: Group A of low runoff potential, Group B of moderate runoff potential, Group C of high runoff potential, and Group D of very high runoff potential.

Cover. Within the meaning of the soil-cover complex, is any cover that provides protection from rainfall energy. Since detailed information about vegetation is often lacking, the cover complex is based upon empirical relationships developed for different kinds of land uses. The approach is to describe cover and land uses as they apply to field conditions that may be estimated visually or with very simple field techniques. Evaluations have been made for crop rotations, native pasture, rangeland, meadows, woodlands, forests, forest-range mixtures, impervious areas, and urban areas (44 45).

Antecedent Moisture Conditions (AMC). Rainfall or snowmelt in the previous 5 to 30 days increases the potential for runoff from saturated soils. Three antecedent moisture conditions (AMC) are used to index field conditions: AMC 1 for dry soils, AMC 2 for average conditions leading to normal annual flood series, and AMC 3 for wet conditions. Runoff Curve Numbers for soil-cover complexes are published for average soil moisture conditions (AMC 2) and is the soil moisture condition normally used for analysis. However, there are tables available to convert AMC 2 to the other AMC classes (44 45).

To estimate storm runoff volume, the method combines antecedent soil moisture condition, rainfall, and the hydrologic soil-cover complex in this equation:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where: Q = direct runoff, inches
P = storm rainfall, inches
S = maximum potential difference between P and Q at time of storm beginning and is a function of the soil-cover complex and antecedent soil moisture from previous rainfall.

For data sets representing the same beginning soil moisture condition, a graph of storm rainfall (P) plotted against direct runoff (Q) for annual floods shows that the quantity (P-Q) approaches a constant (minimum S) as P continues to increase. The changing relationship, (P-Q), as indexed by S, results from the physical processes involving infiltration, interception, surface depression storage, and soil storage; and is dependent on soil moisture levels (antecedent moisture conditions) at the beginning of the storm (46 47 48).

A system of runoff curve numbers (RCN) was established to simplify the use of S factors for soil-cover complexes. Runoff curve numbers range from 0 (where S = infinity) to 100 (where S = 0). As with the S values, runoff curve numbers show the potential to generate direct runoff and are related to S as follows:

$$\text{Runoff Curve Number} = RCN = 1000/(10+S)$$

Figure 2.4 "Estimating Direct Runoff Amounts from Storm Rainfall" shows the relationship of storm rainfall and runoff curve numbers to direct runoff (49). The primary application of these methods is to ungaged watersheds where rainfall and watershed data are normally available. For example, given a storm of 4.3" and a RCN of 74, find runoff = 1.83".

Figure 2.5 "Classification of Soils and Hydrologic Condition" contains narrative statements for soils from low runoff potential to very high runoff potential. For example, deep sands would be hydrologic soil group A.

Figure 2.6 "Runoff Curve Numbers (Average Soil Moisture AMC 2)" yields a runoff curve number for selected combinations of hydrologic soil group and soil surface condition expressed as poor, fair, or good hydrologic condition. For example, the runoff curve number for poor range condition on a HSG C soil is 79.

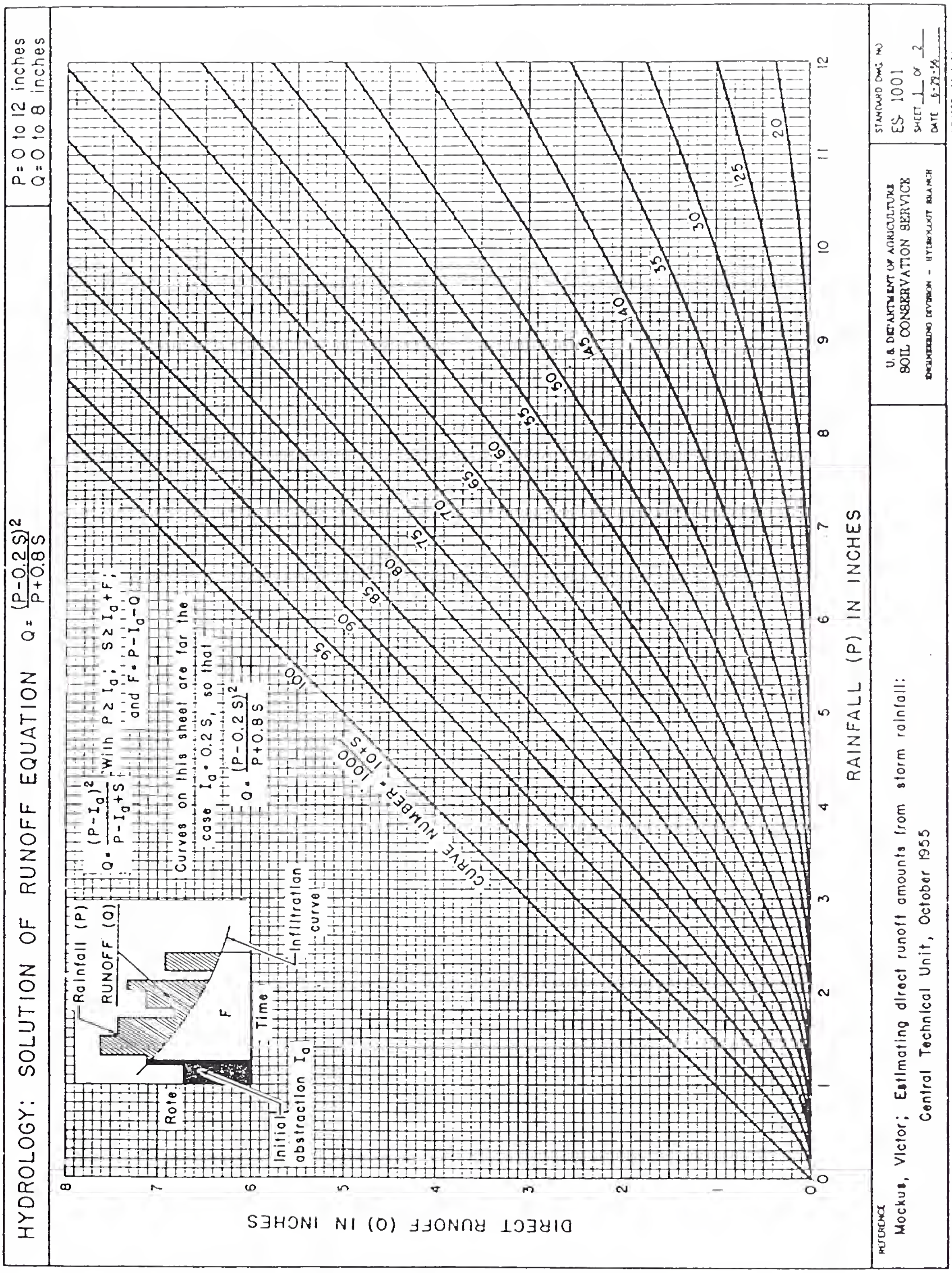


Figure - 10.1 (1 of 2)

Figure 2.4 Estimating Direct Runoff Amounts from Storm Rainfall

Hydrologic Soil Groups (HSG)

A A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

B B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Water transmission rates are moderate (0.15-0.30 in/hr).

C C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. C soils have a low rate of water transmission (0.05.0.15 in/hr).

D D soils have high runoff potential with very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Water transmission rates are very low (0-0.05 in/hr).

HSG are published for about 4000 U.S. soils series. If the soils are not classified or have been disturbed, but not compacted enough to shift to a lower HSG, use the texture of the new surface soil to determine HSG. HSG A = Sand, loamy sand, or sandy loam. HSG B = Silt loam or loam. HSG C = Sandy clay loam. HSG D = Clay loam, silty clay loam, sandy clay, silty clay, or clay.

U.S. Soil Conservtn Srv. 1985. Hydrology. Sec 4 NEH. Ch 7 and TR 55 (Urban Hydrology) Pg A-1.

Rangeland Hydrologic Condition

Cover density (percent)	Plant and litter air-dry weight (tons per acre) Less than 0.5	0.5 to 1.5	More than 1.5
Less than 50	Poor	Poor +	Fair
50 to 75	Poor +	Fair	Fair +
More than 75	Fair	Fair +	Good

U.S. Soil Conservation Service. 1985. Hydrology. Sec 4 NEH. Wash DC. Chap 8. p8.4

Woodland Hydrologic Condition

Poor - Heavily grazed or regularly burned. Litter, small trees, and brush are destroyed.
Fair - Grazed but not burned. There may be some litter but these woods are not protected.
Good - Protected from grazing. Litter and shrubs cover the soil.

U.S. Soil Conservation Service. 1985. Hydrology. Sec 4 NEH. Wash DC. Chap 8. p8.6

Forest Hydrologic Condition

Poor - Compacted. Mull humus (A1 with <5% O.M.) is massive and firm. Mor humus (> 5% O.M.) is felty. Infiltration is impeded. Frost formation is of the concrete type.

Fair - Moderately compacted. Transition stage. Frost formation includes both concrete and granular types; the areal extent depends on the land use and trend in compaction.

Good - Not compacted. Mull humus and mor humus is loose and friable and not massive (mulls) or felty (mors). Infiltration is not impeded. Frost formation is granular or stalactite.

U.S. Soil Conservation Service. 1985. Hydrology. Sec 4 NEH. Wash DC. Chap 9. p9.3

Figure 2.5 Classification of Soils and Hydrologic Condition

Table -- Runoff Curve Numbers - Soil and Cover Complexes

Land use & condition	SOIL A			SOIL B			SOIL C			SOIL D		
	Hydrologic Soil Group - Hydrologic Condition											
	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good
AGRICULTURE												
Cultivated land (1)	72	--	62	81	--	71	88	--	78	91	--	81
Meadow (dry)	--	--	30	--	--	58	--	--	71	--	--	78
Pasture or range	68	49	39	79	69	61	86	79	74	89	84	80
Range pitting	58	37	30*	73	64	48	83	77	72	88	83	79
Range contouring	47	30*	30*	67	59	35	81	75	70	88	83	79
Woods (Tbl 9.1)	45	36	30*	66	60	55	77	73	70	83	79	77
FOREST-RANGE LANDS	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good
Brush land	48	35	30*	67	56	48	77	70	65	83	77	73
Desert shrub	63	55	49	77	72	68	85	81	79	88	86	84
Hrbceous 25 40 50cvr%	--	--	--	78	74	71	85	82	81	91	90	89
Hrbceous 60 75 90cvr%	--	--	--	68	65	61	79	76	73	87	86	84
Junipr Grs 25 40 50%	--	--	--	70	63	58	82	76	73	--	--	--
Junipr Grs 60 75 90%	--	--	--	53	46	39	70	65	59	--	--	--
Oak Aspen 25 40 50%	--	--	--	61	53	48	70	63	58	--	--	--
Oak aspen 60 75 90%	--	--	--	43	36	28	53	47	40	--	--	--
Sagebr Grs 25 40 50%	--	--	--	63	56	51	75	68	64	--	--	--
Sagebr Grs 60 75 90%	--	--	--	46	40	33	59	52	45	--	--	--
FORESTS	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good
Litter protected-												
Humus 0"	56	52	45	75	72	67	86	83	78	91	88	83
" 1"	51	47	37	72	68	61	82	79	71	88	84	77
" 2"	47	42	31	68	64	56	79	75	67	85	81	73
" 3"	44	38	30*	66	61	53	76	72	63	82	78	70
" 4"	41	35	30*	64	59	51	74	69	61	80	75	67
" 5"	38	32	30*	61	57	49	72	67	59	78	73	66
" 6"	36	30*	30*	60	55	47	70	65	57	76	72	64
Not Protected by litter-												
Humus 0"	56	56	49	75	75	70	86	86	81	91	91	86
" 1"	56	51	41	75	71	64	86	82	74	91	87	80
" 2"	51	46	36	72	66	60	82	78	70	88	84	76
" 3"	48	42	31	69	64	56	80	75	66	85	81	73
" 4"	45	39	30*	67	62	54	77	73	64	83	78	70
" 5"	42	36	30*	64	60	52	75	70	62	81	76	69
" 6"	40	33	30*	63	58	50	74	68	60	79	74	67
MISCELLANEOUS SITES	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good	Poor	Fair	Good
Wetlands, impervious	--	--	--	--	100	--	--	--	--	--	--	--
Overflow;subirrigated	--	--	--	95	--	90	--	--	--	--	--	--
V.Shallow (<10" root)	--	--	--	95	--	90	--	--	--	--	--	--
Irreg slps, outcrops	--	--	--	85	--	75	--	--	--	--	--	--
Roads, surface - dirt	74	--	72	84	--	82	90	--	87	92	--	89
Farmsteads, homesites	--	59	--	--	74	--	--	82	--	--	86	--
Gravel sites	--	--	--	45	--	25	--	--	--	--	--	--
Rock	--	--	25	--	--	35	--	--	45	--	--	65

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* RCN's below 30 are set = 30.

Figure 2.6 Runoff Curve Numbers (Average Soil Moisture AMC 2)

Watershed Development

Management of watersheds to conserve soil and water requires that the land be "used within its capabilities and treated according to its needs." The cost and risk involved in watershed development determines the nature of the hydrologic analysis; the objective of which is to minimize risk by conservative design and good construction. Both high-cost and high-risk projects require special geologic and hydrologic studies to avoid unnecessary risk, but the more typical hydrologic analysis can focus on watershed characteristics, precipitation, and runoff from existing and planned activity (50).

In the context of geomorphic equilibrium, adjustable stream channels have upper levels of tolerance to changes in the stream power and sediment loads and the risk of upsetting geomorphic equilibrium is greatly increased as watershed disturbance approaches some upper limit (25 27 30 31).

One difficulty in environmental analysis is displaying complex information about impacts, costs, and risks in easily understood formats. There are two problems: complex material causes confusion and the magnitude of real impacts are easily lost in the detail. With regard to comparisons among watersheds, the display of storm runoff volumes for a design storm is much more difficult to explain than using a simpler but less specific measure like "disturbed area" (37).

For example, the 10-year, 24-hour design storm is the same statistical event, but not necessarily the same <u>amount</u> or <u>intensity</u> for each watershed. For most National Forests and Grasslands, the normal precipitation patterns vary so greatly that displays based on runoff volumes would not be helpful in explaining storm water cumulative effects. By using area "exposed", the differences in rainfall amounts are neutralized -- until such time as a site specific project action is proposed and a design storm selected for mitigation planning.

One way to account for the differences in storm runoff volume generated by different activities and hydrologic conditions is to adjust the contributing area to a common denominator of impervious surface (51 52 53 54 55). For this purpose, unpaved, graded roads are used as the measure of impervious surface because they are extensive, generate maximum storm water volumes, and are often the major disturbance anyway. A simple ratio of runoff volumes for the activity compared to the road (Qact/Qrd), or alternately, infiltration (Srd/Sact), converts each activity into corresponding "impervious" acres (56).

The Watershed Water Quality Assessment lists activities and conditions with the respective area. Each condition is assigned a runoff curve number based upon it's hydrologic properties. The curve numbers are in turn converted to S values and compared to the S value for unpaved roads. These "impervious area ratios" are multiplied by the area of activity (and natural disturbance), then totaled for the watershed. These totals may be called "Disturbed Areas", "Areas Subject to Storm Runoff", "Developed Areas", "Activity Areas", etc. (See Fig 2.7).

This analysis serves two major purposes: first, to display the current knowledge in a way that addresses storm water as an cumulative effects issue; and second, to screen for watersheds that may be approaching upper limits for geomorphic equilibrium or those that need additional watershed condition and stream health inventory before further activity is authorized. With this approach, multiple use planning continues, but with the caveat that field verification may result in either the need for extraordinary mitigation or activity postponement (57).

Watershed 99 . DISTURBED AREA - Existing Condition: 1992

Total Watershed Area: 12,000ac

Activity (from Watershed Water Quality Assessmt) Convert units to acres	Watershed Total acres	Conditn RCN	Sact	Impervis Area Rat Srd/Sact	Disturbed Areas, ac (2 x 5)
Rangelands, poor condtn	250	86	1.63	0.91	228
Forest to burn	400	81	2.35	0.63	252
Active mining sites	55	87	1.49	1.00	55
Roads & trails	47	87	1.49	1.00	47
Partial cut (0 - 5 yr)	217	79	2.76	0.56	122
Partial cut (5 -25 yr)	320	75	3.33	0.45	144
Clear cut, new, no rcvy	175	82	2.20	0.68	119
Clear cut, 10-25yr rcvy	740	78	2.82	0.53	392
Salvage operations	440	86	1.63	0 91	400
Non-regenerated	130	80	2.60	0.60	78
Sub-totals (A)	2774				1837

Activity area estimates from Watershed Water Quality Assessment or similar accounting. RCN = Runoff Curve Numbers from hydrologic survey. Sact = S derived from the actvity RCN; Srd = S derived from the road RCN (chosen as impervious area standard for the watershed). Impervious Area Ratio = Sroad/Sactivity.

A/ 2774 Activity acres is 23% of total; 1837 "Disturbed Area" is 15%.

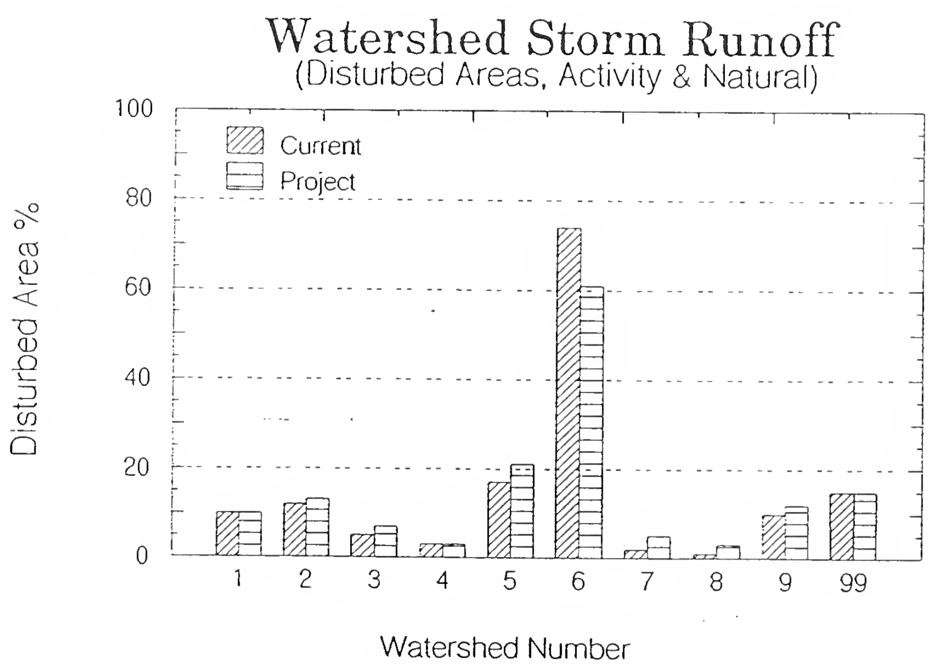

Figure 2.7 "Disturbed Area" Calculation and Watershed Cumulative Effects

Distributed Effects

Streams of streams of streams of streams leading to the one you can hop across are still waters of the United States and are covered by the power and glory of the Clean Water Act. It is not helpful to shift evaluation to the Mississippi - or some other broad plan level - and then proclaim, that because the generalized information shows no effects, that there are, in fact, no effects.

There are at least two watershed assessment models capable of evaluating complex distributed effects for hydrology and sedimentation; both are driven by rainfall events and use Runoff Curve Numbers. Both are capable of evaluating complex problems of the kind suggested by the Watershed Water Quality Assessment. Both models are available in personal computer format with supporting documentation. SEDIMOT 2 was designed to evaluate alternatives associated with permits for surface mine applications involving storm water, sediment generation, and sediment transport (61 62). AGNPS is an agricultural, non point source model designed for rural applications involving storm water, sediment, nutrients from fertilizer applications, and pesticide applications to farmland.

Distributed effects relative to soil and water conservation are of the micro scale and routinely defined below the recognition level of both mapping and database definition. The cost would be prohibitive to include micro detail in these operations, and it is a good decision not to do so. However, while it makes sense not to map a small gully or blowout, the effect on stream health may well extend several miles downstream and can be easily mapped (58).

Stream health maps are essential and can be generated at reasonable cost by experienced people. Such maps reflect results of current and past watershed activity and need to be supplemented with an understanding of soil and water problem areas. First approximations of problem areas can be derived from maps of activities that are located near streams or would be expected to produce high rates of storm flow from disturbed areas that are connected to the stream.

<u>Connected Disturbed Area</u>. In 1986, the SCS updated their technical manual on urban hydrology. The manual now includes methods for hydrologic analysis of areas with extensive pavement, roofs, and concrete gutters that connect with storm sewers. Where such areas are connected to the stream system, the storm water rapidly runs off and results in accelerated peak flows and large volumes of water. The SCS uses the "Connected Impervious Area" as a measure of urban watershed response to storm events.

The "Connected Disturbed Area" is a parallel thought, except that it applies to high runoff areas that may be paved, but are more likely to be dirt or gravel roads, mine spoil, denuded areas, highly compacted by heavy equipment or livestock grazing, or areas rendered nearly impervious from fire effects.

"Connected Disturbed Area" is a good link between the watershed cumulative effects analysis and individual distributed effects. Because of the causal relationship between storm runoff and soil erosion and the damage to stream health, field operations that concentrate on disconnecting "Connected Disturbed Areas" from the stream would be relatively easy to monitor and report. It would also be easier to express the objective of Best Management Practices and develop training for on-site measures that focus on a "disconnecting" objective rather than a morass of detail associated with individual practices.

Antidegradation issues might be addressed by a summation of Connected Disturbed Area; because of the strong correlation between connected disturbed areas and sedimentation, any increase in Connected Disturbed Area will likely result in stream sedimentation and degradation. This makes a good first approximation of antidegradation concerns at the EA stage in planning where alternatives are being formulated.

<u>Nutrient Cycles:</u> Any natural, enclosed system with energy flowing through it, tends to change until a stable adjustment, with self regulating mechanisms, is developed. Self regulating mechanisms are those which cause a return to constancy if a system is caused to change from an outside influence. When a stable adjustment is reached, energy transfers tend to progress in a one-way fashion with characteristic steady rates.

As ecosystems mature, more inorganic nutrients are tied up in biomass and the selective advantage shifts from small species to larger species and individuals with more complex life histories. In undisturbed natural systems, phosphorus is often in chronic shortage and serves as the limiting factor in ecosystems because of it's effect on soil fertility. Other things being equal, ecosystem diversity, stability, and productivity can not be maintained unless the nutrient base, especially nitrogen and phosphorus, is also maintained.

The National Forest Management Act includes the mandate that land productivity shall not be impaired and that destructive activities will be either modified or discontinued. But NFMA does not specifically define impairment or how it is to be measured. The legislative history states that 1) it is carried from the 1960 Multiple-Use Sustained-Yield Act (MUSY), and 2) that "nutrient degradation" is a matter of real concern (59). MUSY, however, does not define impairment, nor mention soil fertility, but it does refer to the "prevention of soil erosion" clause in the 1944 Sustained Yield Forest Management Act (16 USC 583-583i).

The Federal Land Policy and Management Act mandates, among other things, that allotment management plans (AMP) will be written to meet multiple use, sustained yield, economic, rehabilitation, protection, and improvement objectives (60).

Storm runoff can result in accelerated soil erosion which reduces the nutrient base. Runoff Curve Numbers, as an index to storm runoff, are also evaluated on the basis on litter and humus, which provide the power house for the nutrient cycle. The conclusion is that as runoff curve numbers increase as a result of losing litter or humus, then the nutrient cycle is not being maintained. Exactly what the relationship is has not been determined.

Soil erosion and high storm flow rates likely contributes to eutrophication, which is another negative and cumulative effect identified by Clean Water Act. Eutrophication is defined as accelerated biomass production in hydrologic systems in response to increases in phosphorus. Doubling phosphorus commonly doubles the standing crop of plankton and pondweeds; and continues until phosphorus again becomes limiting. The resulting mass is an "algal bloom".

As mentioned before, the EPA has reviewed and commented on dozens of Forest Land Management Plans and their associated EIS's. One major issue raised many times in their formal responses concerned the lack of detail about water quality monitoring and compliance with State and Federal statutes. These EPA comments and subsequent discussions helped precipitate the current efforts in watershed monitoring and modeling efforts (1 25).

The Clean Water Act is the best choice for establishing a solid legal foundation for watershed monitoring as discussed in Part 1. The scope of the monitoring job in connection with antidegradation is emphasized by the list of water quality impacts developed in Part 1, Table 1.2 "Measures of Water Quality - Functions and Effects" (25). They are as follows:

1. Concentration of pollutants thru physical processes.
2. Dispersal of pollutants thru physical processes.
3. Rates of inorganic sediment accumulation.
4. Eutrophication & organic accumulation rates; pollutant concentration and dispersal through biological and chemical systems.
5. Effects on key species, natural temperature patterns, & dissolved oxygen conditions (food, propagation, cover).
6. Effects on natural stream flow patterns (includes road and corridor effects on reach, flow, and circulation).
7. Effects on aquatic ecosystem stability & diversity.
8. Effects on aquatic ecosystem productivity.
9. Effects on hydrologic cycle and storm runoff.
10. Stream health restoration and recovery rates.
11. Comparison of actual condition to Congressional objectives.
12. Comparison of water samples to State water quality standards.

Watershed Water Quality Monitoring table (Fig 2.8) is offered as a basic staff officer summary that presumably would be enough detail for program control; yet would maintain flexibility on a year to year basis. A quick review of the table shows two main items: program management and a monitoring profile associated with each specific water quality impact. Specifying particular impacts and how it will be monitored should help keep the focus on high risk situations.

WATERSHED WATER QUALITY MONITORING

(Staff Officer Watershed Summary)

Date__________

Watershed : Name :

Area sqm : & Id :

Synopsis:

Assignment of responsibility	Monitoring Plan 3 Year $M	--If CWA Failure--
	Current Budget Next	Expctded:
		Restortn:
		Costs $M:

Water Quality Impacts (re: legislative history)	Monitoring Profile						
1. Concentration of pollutants thru physical processes.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
2. Dispersal of pollutants thru physical processes.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
3. Rates of inorganic sediment accumulation.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
4. Eutrophication & organic accumulation rates; pollutant concentration/dispersal thru bio and chemical systems.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
5. Effects on key species, natural temperature patterns, & Dissolved oxygen conditions (food, propagation, cover).	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
6. Effects on natural stream flow patterns (includes road and corridor effects on reach, flow, and circulation).	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
7. Effects on aquatic ecosystem stability & diversity.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
8. Effects on aquatic ecosystem productivity.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
9. Effects on hydrologic cycle & storm runoff.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
10. Aquatic life health restoration and recovery rates. Restoration plans to achieve adequate aquatic health.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
11. Comparison of actual condition to Reference conditions.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft
12. Comparison of ... to State water quality standards.	no	Trd	Ref	Adv	Cwqst	Cadm	Efft

Monitoring program codes: no = no plans; Trd = Trends; Ref = Reference; Adv = Advance warning; Cwqst = Compliance (water quality standards); Cadm = Compliance (admin policy); Efft = Effects.

Figure 2.8 Watershed Water Quality Monitoring

WATERSHED WATER QUALITY MONITORING

Staff Officer Watershed Summary

The watershed responsibility is normally assigned to an appropriate staff officer. This summary is intended as communication of the scope of watershed monitoring to be undertaken. Each watershed is summarized as an individual monitoring project. If there are several watersheds that will be monitored in the same way, they can be summarized together. Otherwise, the objective is to summarize the monitoring by watershed; so that high risk situations or critical watersheds can get appropriate attention.

Watershed Area, sqm. Area in square mile. If there are sub-watersheds, measure the area for each unit.

Name & Id. Watershed name from FSM. Use the local name & # for sub-watersheds.

Synopsis. Brief statement about what is going on. Spotlight any particular problems or projects.

Assignment of Responsibility. Who is going to get this done. Provides a name for later contact.

Monitoring Plan 3 Year $M. Estimate costs for people, travel, and supplies for each of the 3 years.

If CWA Failure -- Expected Restoration Costs $M. This is a risk assessment shown as a cost of stream repair related to restoring the stream to appropriate standards.

Water Quality Impacts (re: legislative history). This list is intended to make monitoring plans specific about what information is being collected and what part of the legal requirements are served.

Monitoring Profile. Review of FS manuals, memos, handbooks, and technical advisories indicates many kinds of monitoring; grouped into 5 basic technical objectives that are not mutually exclusive. The current terminology includes "implementation, validation, and effects"; these reflect management objectives and can be blended into the T*R*A*C*E objectives. See the Watershed Sciences Glossary for complete description.

- T Trend monitoring - a primary long term data collection effort designed to detect trends. Provides statistical base line for comparing current events with long term patterns.
- R Reference monitoring - designed to quantify and evaluate physical, chemical, and biological parameters of undisturbed sites on representative ecological situations.
- A Advance warning system monitoring - a continuous, on-going effort to identify conditions that are or could lead to environmental deterioration, health and safety hazards, or emergency response.
- C Compliance monitoring - comparison of project results and effects with established state water quality standards and with administrative standards (i.e. Forest Service standards & guidelines, contract clauses, Special Use Permits, 404 Dredge & Fill Permits).
- E Effects monitoring - determination of relationships between climate, geology, vegetation, soil, and management factors on selected physical, chemical, and biological factors.

AGNPS	Agricultural Nonpoint Source model
AMC	Antecedent Moisture Condition
AMP	Allotment management plan (FLPMA)
BMP	Best Management Practices
CEQ	Council on Environmental Quality; established by NEPA
CFR	Code of Federal Regulations
Court citations (Volume and page; i.e. 731 F.Supp 970 (D.Colo 1989))	
9 Cir	9th Circuit Court of Appeals
D.Colo	Colorado Federal District
F.2d	Federal Reporter, 2nd series
F.Supp	Federal Reporter, supplements
S.Ct	Federal Supreme Court Reporter
CWA	Clean Water Act, as amended, from 1948 to 1987.
EIS	Environmental Impact Statement.
EPA	U.S. Environmental Protection Agency.
FLMPA	Federal Land Management Planning Act
FSM2500	Forest Service Manual, 2500 Section
FSH3509	Forest Service Handbook, 3509 section
HSG	Hydrologic Soil Group (A, B, C, D)
MUSY	Multiple Use Sustained Yield Act, 1960
NEPA	National Environmental Policy Act, 1969.
NFMA	National Forest Management Act, 1976.
NPDES	National Pollution Discharge Elimination System permits
RCN	Runoff Curve Number
ROD	Record of Decision; required by NEPA
SCS	Soil Conservation Service, U.S.Dept of Agriculture
SEDIMOT	Sedimentation model with distributed effects
USC	U.S. Code
USCA	U.S. Code Annotated
USCC&AN	U.S.Code Congressional and Administrative News
WWQA	Watershed Water Quality Assessment

1 Maxwell 1991.
2 Watershed cumulative effects with appropriate measures of aquatic habitat reduction (843 F.2d @1195 and 753 F.2d @759) and economic damage to fisheries (701 F.Supp 1473).
3 Sidle & Hornbeck. 1991. Cumulative effects re to water quality. p271.
4 Rio Grande National Forest plan was remanded (Citizens for Environmental Quality v. U.S. 731 F.Supp. 970 (D.Colo 1989)). Federal case law directs forest plan to correct (among other things) for failure to address several watershed issues:
- failure to identify the technology that would be employed to prevent irreversible damage to soil resources; otherwise, the land is unsuited because timber harvest creates irreversible resource damage to soils productivity and/or watershed conditions. (36 CFR 219.14(a)(2)).
- failure to address compliance with the Clean Water Act (36 CFR 219.23(d);
- failure to obtain and use current information (36 CFR 219.12(d));

5 36 CFR 219.12(d) The Supervisor will assure that the interdisciplinary team has access to the best available data. The interdisciplinary shall collect, assemble, and use data, maps, graphic material, and explanatory aids, of a kind, character, and quality, and to the detail appropriate for the management decision to be made. .... Data and information needs may vary as planning problems develop from identification of public issues, management concerns, and resource use and development opportunities.
6 NFMA 36 CFR 219.23 Water and soil resource (paraphrased) states that Forest Planning shall provide for (a) estimates of current water use, including instream flows; (b) identification of significant impoundments, wells, transmission facilities, and other man made developments; (c) estimates of the probable occurrence of various levels of water volumes; (d) compliance with the Clean Water Act, Safe Drinking Water Act, state & local requirements; (e) evaluation of existing or potential watershed conditions that will influence soil productivity, water yield, water pollution, or hazardous events; and (f) adoption of measures to minimize risk of flood loss, to restore and preserve flood plain values, and to protect wetlands.
7 Plan scoping (40 CFR 1501.7) identifies significant issues; defined in part as those likely to be controversial (40 CFR 1508.27(b)(4) or those likely to threaten a violation of Federal, State, or local law or requirement. Water quality and stream health issues are nearly always significant issues from land disturbing activities.
8 Anderson 1987.
9 Arjo 1990.
10 Braun 1986.
11 Coggins 1991.
12 Whitman 1989.
13 Odum, page 16 and 20.
14 Odum, page 20.
15 See also George Perkins Marsh (1864) for a depressing account of human inability to learn anything about resource stewardship.
16 Leahy, Patrick (Sen-D). 1990.
17 U.S. Forest Service. 1990.
18 Horton. 1988.
19 36 CFR 219.12(k) requires evaluation of how well the objectives are being met; requires documentation of effects, including significant changes in productivity of the land.
20 U.S. EPA 1989.
21 U.S. EPA 1985.

22 Rupp 1983.
23 Schmidt 1987.
24 U.S. Congress.
25 Ohlander 1992. Part 1.
26 Flinn & Reimers. 1974
27 U.S. Forest Service. 1980. (WRENNS)
28 Lofstedt 1984 to 1989.
29 EPA's Forest Plan water quality review checklist (11/5/85).
EPA letter to Greybull District Ranger re water quality (10/16/87).
" " " Shoshone National Forest re water quality (8/7/87).
" " " Shoshone National Forest detailed comments (8/7/87).
" " " Grand Mesa, Uncompahgre, and Gunnison NF (9/24/87.
" " " Black Hills National Forest re water quality (12/8/87).
30 Dunne & Leopold 1978.
31 Silvey & Rosgen 1980.
32 FSM 2513.2 standardizes an 11 character watershed coding: levels 1-4 for Hydrologic Unit Code (8 digits); level 5 (2 digits) for major National Forest and Grassland watersheds (FSM R2 supplement); and level 6 (1 character) for subdivision. NFS specified watersheds consist of 3 characters, i.e. 12B, and are more or less 4th order watersheds.

Watershed code scheme is manual policy; I apply the logic that the policy watersheds reflect the level of accounting to be used in meeting the requirements specified by the remand in 36 CFR 219.23 & 36 CFR 219.23(d).
33 EPA. 1991. Storm water regs at 40 CFR 122. See also appendix A.
34 CWA S 402(p) M & I Stormwater Discharges. Applications include activities, area disturbed, runoff coefficients, and changes in the area of impervious surfaces (40 CFR 122.26(b)(11), (b)(13), (c)(1)(ii) and (d)(1)(iii)(B)(2).
35 Barfield. 1983. p18 table reference to surface mines.
36 Dunne & Leopold. 1978. p54 on probability.
37 Bevenger, Greg. 3/92 Discussions of stream health and cumulative effects.
38 Ohlander. 1992. Part 1. Evidentiary standards. Pg 1-11 and Appendix B.
39 Runoff Curve Number methods are applicable to many soil-cover complexes including forest and range hydrologic conditions researched by the Forest Service; are not limited to small (200 acres) watersheds; can be validated with local gaged watersheds; has an understandable physical meaning that combines infiltration and initial abstractions; has readily available documentation, computer software, and training packages; and has a long history of agency sponsorship and use.
40 Hobba, Bob. circa 1972. Conversations about runoff curve numbers.
41 A list of commonly referenced hydrology handbooks that include forest and range related runoff curve numbers include:

Barfield, B.J., R.C. Warner, and C.T. Haan. 1983. Applied hydrology and sedimentology of disturbed lands. Okla Tech Press. Stillwater OK.603p.

Chow, Ven Te. ed. 1964. Handbook of Applied Hydrology. McGraw Hill. 1000+ pages.

Daddow, Richard L. 1986. SEDIMOT II Computer model - Introduction and application on National Forest Lands. Transmitted by David G. Unger, Director of Watershed and Air Management, Forest Service, Wash DC.

Dunne,T. and Luna B. Leopold. 1978. Water in environmental planning. W.H. Freeman & Co. New York. 818 pg.

U.S. Bureau of Reclamation. 1977. Design of small dams. Wash DC. 816pgs.

U.S. Soil Conservation Service. 1985. Hydrology. Section 4 National Engineering Handbook. (Updates of material dated 1964 to 1972.) Wash DC. 500± pgs.

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42 Chow. 1964. page 21-11

43 In 1985, the Forest Service formally terminated active publication of many FS handbooks as a means of reducing administrative costs. The hydrology handbooks, FSH 2518 Forest and Range Hydrology and FSH 3509.12 Methods of Hydrologic Analysis, were both deleted. The handbooks have not been re-issued because the general methods are now common to the literature and special procedures developed by the Forest Service have been incorporated by the Soil Conservation Service in their National Engineering Handbook.

44 Chow. 1964. page 21-11, 21-25, 21-26, 22-47

45 Dunne & Leopold 1978. p 297

46 U.S. Bur. of Rec. 1977. p 540.

47 The rainfall-runoff relationships were developed from the records of numerous small area experimental watersheds. Since nonrecording 24 hour precipitation stations are much more numerous than recording stations, the relationships are built from the nonrecording data set and thus may represent one or more storms in the same daily total. Rainfall intensity and time distribution is therefore ignored. Bur. of Rec. 1977. p 62.

48 Barfield. 1983. p79-80.

49 SCS. 1985. Hydrology pg 10.21. graph solution to runoff - RCN equation.

50 Chow. 1964. pg 21-4.

51 Dunne & Leopold. 1978. p272.

52 Dunne & Leopold. 1978. p168.

53 Dunne & Leopold. 1978. p297, 298, 299.

54 Barfield. 1983. p83, 86; impervious areas promote rapid runoff response.

55 SCS. 1986. p2-4, -10 graphs of the difference in runoff response if impervious are connected to the stream system compared with impervious areas that are dispersed and disconnected.

56 Areas converted to a unity equal to road surface runoff allows the analyst to display a single index for total watershed storm runoff impacts. It can be graphed with watersheds on the x axis and acres (or percent area) on the y axis. The watersheds need to be about the same size to avoid problems of interpretation. For example, stream miles change more or less as the 0.6 power of area; so if an area increases in size from 4 to 8, the same area impact percent will accelerate stream health impacts because the stream length only increased from 2.3 to 3.5.

57 Bevenger, Greg. 3/92. Shoshone National Forest discussions on watershed thresholds: this approach does not establish or use a threshold other than that imposed by the antidegradation standards from the Clean Water Act.

58 EPA and State water quality agencies are currently exploring river reach data files that can be used to summarize statewide water quality assessments for the CWA S 319 report. Reach identification is on the order of 20 mile segments.

59 NFMA quote: "The Committee intends that an overall program of on-the-ground monitoring, coupled with research, insure the sound management of National Forest System lands. .... If research or evaluation establishes that a management system or method is producing impairment of the productivity of the land, such system or method will be modified or discontinued."

"The subject of "nutrient degradation" on forest soils is a matter of real concern. Additional research and more comprehensive monitoring and

evaluation of nutrient degradation is a high priority example of the benefits expected from sound application of the research and evaluation provision of the Committee bill." [76 USCC&AN 6699].

60 FLPMA 43 CFR 1701-1782 added this criteria and associated time frames.

61 Daddow 1986. Transmittal letter for SEDIMOT 2 model use on NFS.

62 Warner et al, 1983; Wilson, et al 1981; and Wilson et al 1983.

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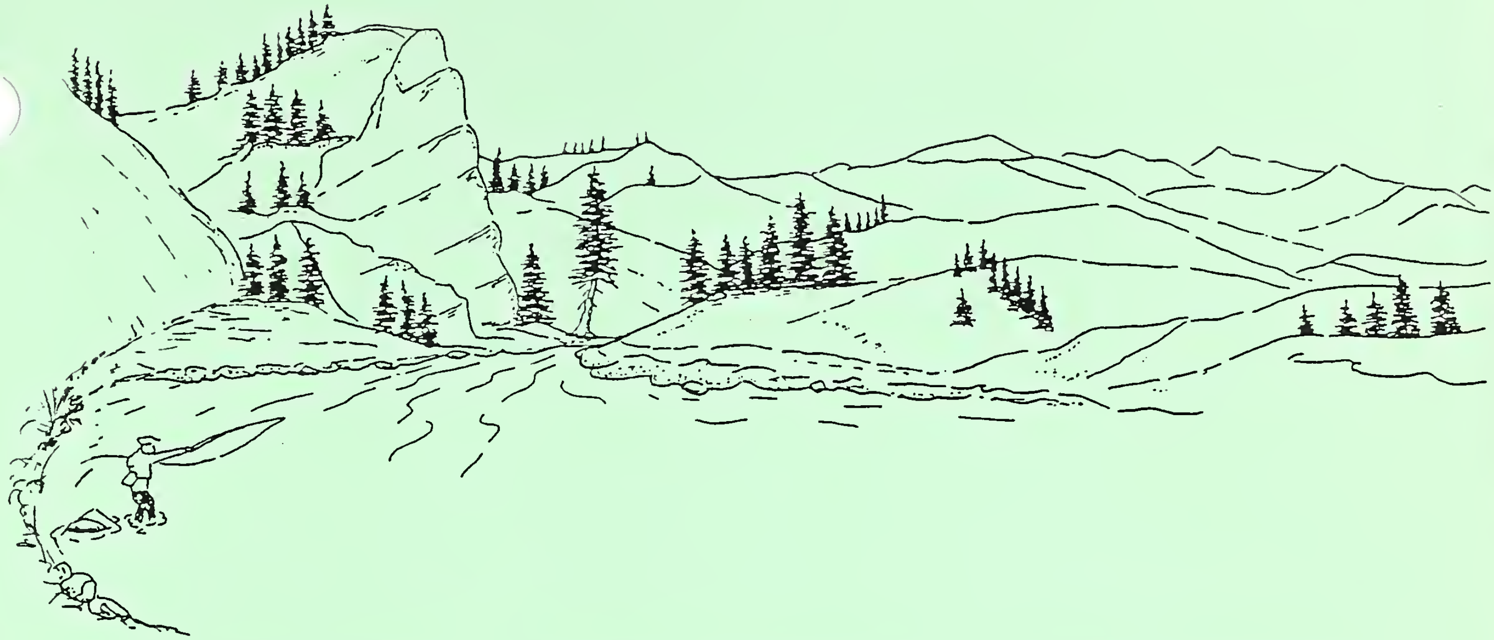

WATER RESOURCES ANALYSES

--- *CLEAN WATER ACT* ---

MONITORING and EVALUATION

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- Part 7. T-Walk Training

- Syllabus -

End Date 1/95

REGION 2

CLEAN WATER ACT - MONITORING AND EVALUATION

Part 7. Stream Reach Monitoring - T-Walk Training

Syllabus to Establish Background and Rationale.
(Companion to Part 8. Syllabus to establish proficiency)

Coryell A. Ohlander

U.S.D.A., Forest Service
Region 2, Denver

March 1994

CLEAN WATER ACT - MONITORING AND EVALUATION

Stream Reach Monitoring - T-Walk Training

Part 7. Syllabus to Establish Background and Rationale.

<u>Table of Contents</u>

Comments to:
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March 1994

Terminology and Abbreviations

BMP — Best Management Practices
CFR — Code of Federal Regulations
COE — Corps of Engineers, Dept of Army
Court citations (Volume and page; i.e. 731 F.Supp 970 (D.Colo 1989))
- 9 Cir — 9th Circuit Court of Appeals
- D.Colo — Colorado Federal District
- F.2d — Federal Reporter, 2nd series
- F.Supp — Federal Reporter, supplements
- S.Ct — Federal Supreme Court Reporter

CWA — Clean Water Act, as amended, from 1948 to 1987.
d50 — Diameter equal to or less than 50% of standard pebble count.
d84 — Diameter equal to or less than 84% of standard pebble count.
EA — Environmental Assessment - NEPA documentation.
EIS — Environmental Impact Statement - NEPA documentation.
EPA — U.S. Environmental Protection Agency.
ESA — Endangered Species Act
FIELDSCRIPT — an acrostic for several aspects of photographic evidence
FLMPA — Federal Land Management Planning Act
FSM2500 — Forest Service Manual, 2500 Section
Gdp — Gully depth re: roads and ditches; part of Vbfr.
LFH — Litter, fermented, and humus materials combined
LWD — Large woody debris, material greater than 4" diameter.
mg/l — Milligrams per liter
NEPA — National Environmental Policy Act, 1969.
NFMA — National Forest Management Act, 1976.
NWP — Nationwide Permits; part of S404 dredge and fill program (COE).
OGC — Office of General Council
ONRW — Outstanding National Resource Waters
Qbf — Discharge at bankfull stage.
Rms — (Road cross drain spacing/1000 x Road Slope%); Part of Vbfr.
ROD — Record of Decision; required by NEPA
snooper — Device with a window for looking at stream beds
STOMPED — Acrostic for water quality: Sediment, Temperature, Oxygen, Metals, Poisons, Equilibrium, and Dissolved salts
SWPPP — Storm Water Permits; and pollution prevention plan (S402(p)).
T-Class — Thalweg classification based on stream physics and materials.
T-Depth — Thalweg depths along a 1/8 mile reach.
T-Standard — Thalweg Standard used as a reference condition.
T-Stick — 5' long 1x1" hardwood stick marked with different scales.
T-Walk — Thalweg and Watershed Area LinK
Thalweg — Thread of the stream
TSR — Tarzwell Substrate Ratio, a measure of macroinvertebrate production.
USC — U.S. Code
USCA — U.S. Code Annotated
USCC&AN — U.S.Code Congressional and Administrative News
UTM — Universal Transverse Mercator coordinates (common on 1:24000 maps).
Vbfr — Vegetative buffer equation for roads and trails.
Vcvr — Buffer type, live plant cover, wood, and coarse litter. Part of Vbfr.
WRENSS — Water Resources Evaluation of Nonpoint Silvicultural Sources.

CLEAN WATER ACT - MONITORING AND EVALUATION

Part 7. Stream Reach Monitoring - T-Walk Training

Reporting on water quality under the Clean Water Act has a watershed focus and includes a problem analyses of current trends, quantification of waterbody health, risk assessment of selected watersheds and activities, a summary of watershed damage control programs, and a summary of improvement actions to be taken. The value of an Advance Warning System is to identify problems early and save money and resources by prompt action. The purpose of T-Walk is to identify facilities and/or activities that fail to meet management criteria; identify stream health deterioration; and to identify corrective actions.

The reader should have read "Part 1 Legal Framework" and accept the idea that monitoring parameters that change rapidly under land use impacts will make a useful advance warning system (1 2). This part builds the rationale for T-Walk in a watershed context and focuses on selected water quality program objectives:

- train/convince field people to immediately take care of small problems.
- report results in terms of Stream Health.
- commit people and authority to stay on top of high risk activities.
- organize and train field people in simple field screen techniques.
- routine evaluation of aquatic diversity and productivity.
- concentrate on attitude adjustment and training at field level.
- concentrate on eliminating personal levels of liability.

The specific educational objectives are predicated on the assumption that a sound, though rudimentary, water quality assessment can be made by field people without specialized training in aquatic biology. Specifically:

-- to quantify and document facilities and/or activities that contribute to water quality deterioration in selected stream reaches;

-- to compare existing conditions against an appropriate reference site and determine stream health based on diversity and productivity; and

-- to write a simplified plan for corrective actions that incorporates an understanding of physical stream processes.

Current experience suggests that understanding 'why' needs to come first before the 'how-to'** training is effective. It also appears that 5 days is the minimum needed to develop the understanding and field skills. The 5 days is 'doing' lapse time and can be split up. For example, a 2 day session on 'why' followed by 2 field days later and a final check up day would work. Be aware, however, that Stream Health evaluations will never be easy and that 5 days is just enough start to help level out consistency and strengthen confidence.

You will need a copy of the T-Walk form and field manual (3). The items marked with a ">>>>" are direct from the field manual. There is nothing cookbook about T-Walk; there is nothing easy about Stream Health assessment; there is nothing easy about Stream Health restoration. The T-Walk interpretation of Stream Health is (probably) overly concerned with the detail in limiting factors. The point is to provide a specific rationale for particular restoration measures - the better the detail, the better the chance for solid understanding and accomplishment.

** See 'how-to' in part 8.

>>>> Water Quality Goal

Protect the physical, chemical, and biological integrity of the nation's water. [Clean Water Acts 1948, '72, '77, '87]

The best place to begin is with a simple two part rationale from Fundamentals of Ecology by Eugene Odum: First, a human's minimum ecosystem is the watershed; this includes terrestrial and aquatic systems, humans and all artifacts, functioning as a system. Aquatic ecological stability over a period of years is very much determined by energy input and the rate of water and materials transported from the watershed (4).

Second, a total ecosystem appraisal must be based on coordinated measurements of standing crop and rates of functions such as self-maintenance of populations, diversity of species mixtures, and trophic structure (4).

This ecological rationale fully supports the legislative history of Clean Water Act. Biological integrity is part of the water quality objective; and together with physical and chemical integrity is considered the same goal as ecological balance, ecological cycle, and ecological integrity. Key concepts include:

- definition and measurement of diversity, productivity, and stability is referenced to an aquatic community found in natural and pristine conditions;

- that pristine is the most healthy situation; and,

- perturbations create two basic impacts: 1) non-selective reduction of individuals (as a flood would destroy individuals and habitat); or 2) selective loss of species (as from different chemical pollution tolerance).

If a stable ecosystem has resulted from human intervention, and the imposition of a pristine standard does not make financial or ecological sense, then the pristine goal is modified to incorporate the new ecology. For example, where non-native fish now form the basis of productive aquatic ecosystems; there would be no point in trying to return these streams to pre-settlement conditions (5).

For multiple-use forestry to be viable, management systems must blend land productivity economics with pollution control constraints; and it is long-term, not short-term, economics that determine the competitiveness of forest products with other geographic areas and with substitute, nonwood products (6).

In particular, good management systems need to encourage the types of pollution control and activites that make future pollution control easier and operate with low total yields as well as control of temporary peak pollutant yields. Factors likely to be part of such a system will vary to match the use pattern appropriate for the land; be geared to the life cycle of the forest; insure physical stability of the forest system, including resistance to wildfire, resistance to disease, and general resistance to land movement; and, insure forest ecosystem stability and adherence to good silvicultural procedures. These can be blended using some form of systems analysis to provide rational policy and decisions about the use of specific control measures. (6 7).

>>>> Striving towards and maintaining the pristine state minimizes the burden to society in maintaining a healthy environment and the stable biosphere that is essential to human well-being. [3742 USCC&AN 1972]

Operating at pristine levels of water quality is the cheapest for society in the long term; these reflect the highest sustainable rates for the waste clean-up duty. Loss of the highest rates means somebody now or in the future pays the cost. And...The Clean Water Act is primarily about economics.

"...[T]he pristine state ... minimizes the burden to man in maintaining ... the well-being of human society." is part of the Congressional intent [3742 USCC&AN 1972]. Hard line based on the 25 years of legal battles and mass of evidence that environmental tampering can have, and has had, unexpected catastrophic effects on resources and economic viability. The statement -- "minimizes the burden to man" -- is long term, self-interest, and economic.

Congress uses "pristine" to define the end point where natural processes are at long term maximum effectiveness. Impaired natural processes generate economic loss, reduced public health, lower quality of life, loss in future options, and potentially large clean up costs.

The preceding position is being implemented, at least in part, under EPA antidegradation regulations. One good definition and rationale is from the one used by the Colorado Attorney General in a 1985 superfund lawsuit (8), to wit:

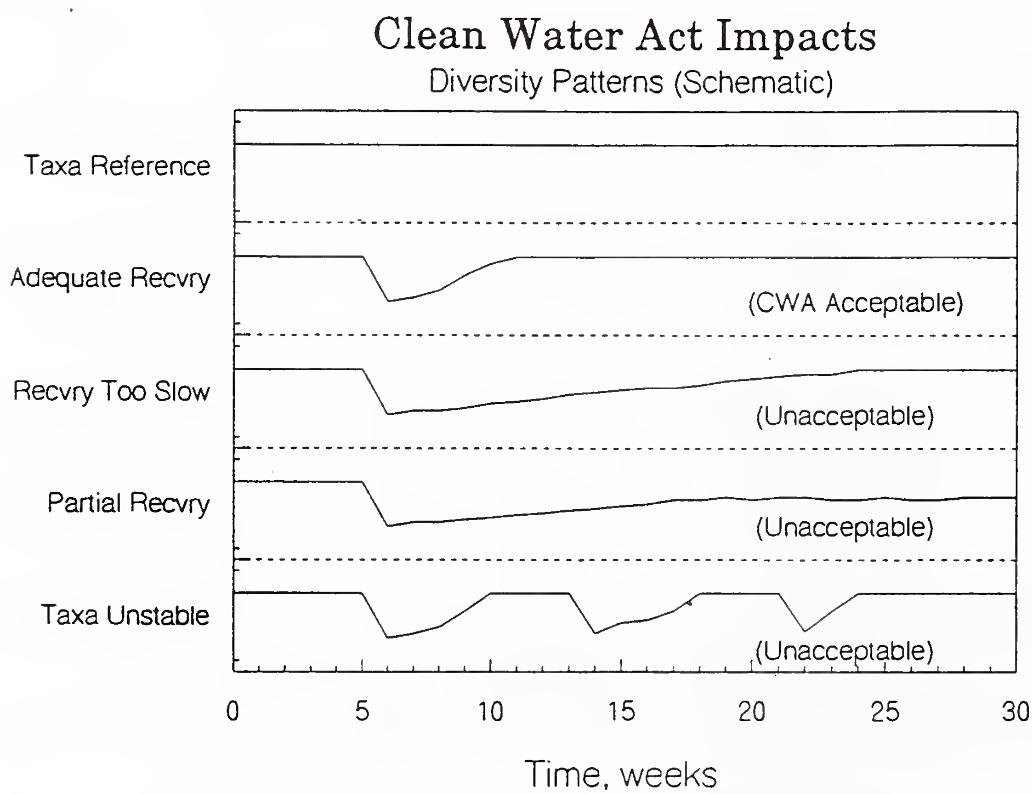
a Any reduction in the quality of state waters injures the public welfare and the environment.
b Increases in the levels of pollutants over background reduce the margin of safety for public health, welfare, and the environment. Remedies that use the increment between background and harmful levels inappropriately increases the vulnerability of the public and the environment.
c Scientific knowledge about harmful levels of pollution is changing. Any pollutant increase above background inappropriately forces the public, rather than responsible parties to bear the risk of current scientific uncertainty.
d Standards set above background commits public resource to a private, unproductive use that precludes future beneficial uses. It is inappropriate to require the public and future generations to bear such costs.
e Water quality standards are dynamic, tend to reflect existing conditions, and are generally not based on appropriate ultimate water quality goals. Many parameters either have no standards or do not adequately account for bioaccumulation, differential sensitivity of organisms, or ecosystem functioning. Given these deficiencies, existing regulatory standards do not always adequately protect the public health and welfare or the environment.
f Injuries to the public health and welfare and the environment can be effectively mitigated and minimized only by a remedy which achieves background levels. Reliable and adequate protection of future generations, and the environment can be achieved only by a permanent solution.

>>>> Maintenance of such integrity requires that changes in the environment resulting in a physical, chemical or biological change in a pristine water body be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original. [3742 USCC&AN 1972]

Because temporary upsets are forgiven, the monitoring problem is with long term effects on processes and maintenance of functions. The kinds of functions most likely to be upset for long term include changes in sediment regimes, upsets in temperature regimes, upsets in oxygen and oxidation regimes, the inclusion of metal contamination within basic life processes, generic or specific poisoning of community members, upsets or shifts in watershed geomorphic equilibrium, and upsets within dissolved chemical regimes such as nutrients and salts. There are 2 things an evaluation needs to accomplish:

1) define the energy and material transport relationships for the major natural processes likely to be impacted by the activities; and

2) describe pristine conditions in terms of measurable chemical, physical, and biological parameters.



>>>> Antidegradation requires that existing uses actually attained in the water body on or after November 28, 1975, shall be maintained and fully protected; the protection is dependent on physical as well as chemical factors and includes substrate suitability, cover, flow, depth, pools, riffles, and the like. [40 CFR 131.12 & .10g].

States must provide for antidegradation and this includes the protection of existing uses attained on or after November 28, 1975. The State may not assign a designated use that is less than an existing use (40 CFR 131.6 & .12). If the State sets a designated use to be achieved (i.e. greater than existing use) and then finds that physical or chemical factors limit attainment of that use; it may back off the previous designated use and redefine uses that can be achieved. The minimum acceptable designated uses are those that result from implementation of regulatory effluent control and best management practices. The factors and their application are listed in 40 CFR 131.10g:

- naturally occurring pollutants that prevent a higher use; or
- seasonal water flow conditions that prevent a higher use; or
- human caused damage that is better left alone; or
- hydrologic modifications and operations prevent a higher use; or
- where current effluent performance standards are not satisfactory; or
- where natural physical conditions (substrate, cover, flow, depth, pools, riffles, and the like) prevent a higher use.

There are three major points: 1) physical habitat is part of antidegradation; 2) physical habitat is present in all situations; and 3) unless the biological system has been overwhelmed, as from the first five on the list, the physical habitat conditions set the limiting factors and the antidegradation floor.

From a regulatory standpoint, however, most of State and EPA effort have been concentrated on the chemical side of the antidegradation question; with no regulatory program for physical conditions, there is no State enforcement. However, physical conditions are a part of CWA S404 and these regulations can be enforced as a matter of federal law (CWA S309(c) & 404(s)). EPA policy also says that, except for Outstanding National Resource Waters (ONRW), the "existing use" requirements of antidegradation are met if the activity does not cause or contribute to "significant degradation" of the aquatic environment as defined by the S404 "b1" Guidelines (40 CFR 230.10(c)) (9).

> "... significant adverse effects on ... (2) on the life stages of aquatic life and other wildlife dependent on aquatic ecosystems, including the transfer, concentration or spread of pollutants or their byproducts beyond the site through biological, physical, or chemical processes; (3) on ecosystem diversity, productivity, and stability, including loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate ...."

T-Walk assumes that the failure to maintain the physical conditions constitute 'degradation' and is a NEPA threshold determination because of antidegradation rules. The measure of substrate, cover, flow, depth, pools, and riffles to support existing aquatic life is therefore a key determination in T-Walk.

Sites degraded after 1975 have priority for restoration and can be justified based on current liability. Also, any future designated use that can be met by improving physical conditions is justification for restoration efforts.

>>>> "Aquatic environment" and "aquatic ecosystem" means "waters of the U.S." that serve as habitat for interrelated and interacting communities and populations of plants and animals. This includes waters and their impoundments such as lakes, rivers, streams, intermittent streams, mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds; or their tributaries. (40 CFR 230.3(c&s)).

The definition for "waters of the U.S." has extensive regulatory implication for land use planning and implementation. At the planning stage, the definition of what areas are, or are not, part of the "waters of the U.S." determines which regulatory framework(s) planners must account for in terms of both analysis and NEPA documentation. At the implementation level, the delineation of "waters of the U.S." generally, and "special aquatic sites" specifically, again determine which of the S404 regulatory conditions or permits apply.

"Waters of the U.S" includes federal lands and those used for public recreation, timber harvest, grazing, mining, or situations where interstate commerce applies (40 CFR 230.3(s)(1)). Tributaries include well-defined or scoured channels, those that show evidence of developing sufficient head of water to move debris or erode the channel, or which may develop such characteristics if diverted or blocked by logging activity (10 11). NFMA (16 USC 1604) supports this definition and requires timber harvest to protect water bodies and fish habitat from water temperatures changes, channel blocakage, or stream sedimentation.

Additionally, definitions for "special aquatic sites", including wetlands, also play a major part in the CWA S404 regulatory framework; they are paraphrased as:

> Special aquatic sites have special characteristics of productivity, habitat, wildlife protection, or other important or easily disrupted ecological values. They include sanctuaries, refuges, wetlands, mudflats, vegetated shallows, coral reefs, and riffle and pool complexes. [40 CFR 230.3(q-1)].
>
> Wetlands are areas inundated or saturated often enough to support, and normally do support, vegetation typically adapted for life in saturated soil conditions such as swamps, marshes, bogs, or similar areas [40CFR 230.3(t)].

It is important that the criteria for mapping such "waters", and any associated "special aquatic sites", be done in a way that complies with the regulations and is regionally consistent. The current USFS, Region 2, policy is to prepare a 1:24000 scale map atlas with "waters of the U.S" defined for use at the implementation stage. The criteria, developed by the Integrated Resources Inventory project team, includes 3 main steps: extension of the stream network based on the map contours, review of aerial photographs as necassary to resolve questions, and a final field check on sites that are still questionable (12).

The mapping and field verification leads to one of 3 possibilities:
1) channels not on the atlas are not "waters of the U.S";
2) channels that are "disconnected" from the main stream network only become "waters of the U.S." at the point that contains special aquatic sites;
3) all channels in the connected network are "waters".

>>>> SELECTED WATER QUALITY CASE LAW

Water quality is commonly seen as a constraint or interference with 'business as usual' rather than as an element of long term economic stability. However, case law demonstrates that taking short cuts in either water quality implementation or planning has substantial risks for the organization and the individual.

>>>> The guiding star is the intent of Congress to improve and preserve the quality of the Nation's waters and all issues must be viewed in light of such intent. 612 F.2d 1231; 540 F.2d 1023; 97 S.Ct 1340 & 1672.

The effective use of scarce resources requires implementing procedures to identify and correct on-the-ground problems. High on the action list is training for field people in the best ways to meet the intent and stay out of trouble. Be aware, that while frequent meetings with regulatory agencies and development of agreements may be useful, the actions themselves are not a substitute for either performance or compliance.

>>>> CWA is broad and remedial, and is intended to restore and maintain natural chemical, physical, and biological integrity. 438 F.Supp 945.

The Forest Service retains deep pocket responsibility for its actions. This does not transfer with special use permits, contracts, or agreements. A history of land abuse, particularly in riparian areas, is no guarantee that a court decision will allow such abuse to continue, or that the required change won't be abrupt. Land management agencies simply do not have the authority to condone abusive land use practices - regardless of the politics. If damage remains, there is no statute of limitation.

In the early stages of damage, the expense of stream restoration is about 20 times greater than the cost of preventing the problem to start with. And costs escalate with delays in corrective action. A major court award for fixing a problem that could have been prevented is not the way to impress your boss.

>>>> Agents may be subject to liability for wrongful acts either in tort or in contract [728 F.2d 1006]. An agent's personal liability is not affected by the fact that it acted on behalf of its principal [525 F.Supp 1104].

Do your job. Failure to exercise authority and responsibility carries liability.

Costs of adequate program control, including basic monitoring, are part of the program cost; they are not a separate budget issue.

Environmental Impact Statements and approved plans are contracts. Write specifically and carefully and with full knowledge of how to get it done. If there is no real possibility, then say so. This is not a poker game.

>>>> MANDATORY BEST MANAGEMENT PRACTICES

>>>> CWA S404(f)(1)(E) Exemption requires construction and maintenance of permanent and temporary roads and skid trails in accordance with BMPs to assure that flow & circulation patterns and chemical & biological characteristics of "waters of the U.S." are not impaired, that the reach is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. Mandatory S208* & COE [33 CFR 323.4(a)(6)] BMPs are paraphrased as follows:

>>>> 1 limit road & trail system to the minimum feasible number, width, and total length consistent with the specific operations, topography, and climate;
>>>> 2 except at crossings, all roads and trails* shall be located sufficiently far from streams or other water bodies to minimize discharges; [* -- S208 and S304 add "trails"];
>>>> 3 crossings shall not restrict the passage of expected floods flows;
>>>> 4 fills shall be stabilized during & after construction to prevent erosion;
>>>> 5 minimize equipment disturbance in "waters" outside construction zone;
>>>> 6 minimize vegetative disturbance in "waters" during and after construction;
>>>> 7 road crossings shall not disrupt the movement of resident aquatic species;
>>>> 8 take borrow material from upland sources whenever feasible;
>>>> 9 the discharge shall not take, or jeopardize the continued existence of, a T&E species, or adversely modify or destroy critical habitat;
>>>> 10 avoid discharges into migratory waterfowl habitat, spawning areas, and special aquatic sites [40 CFR 230.10(a)(3)]; special aquatic sites include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, and riffle and pool complexes. [40 CFR 230.3(q-1)].
>>>> 11 discharge shall avoid areas in or near public water supply intake;
>>>> 12 discharge shall avoid areas of concentrated shell fish production;
>>>> 13 discharge shall avoid National Wild and Scenic River System reaches;
>>>> 14 discharge material will be free from toxic pollutants in toxic amounts;
>>>> 15 all temporary fills will be removed and restored to original elevation.

It is CWA S404(f) that provides <u>Exemptions</u> from the COE S404 permitting process for pollutant discharges into "waters of the U.S." It is CWA S404(f)(1)(E) that creates "no impairment" criteria for roads. It is 33 CFR 323 that implements S404 for COE permits as well as describes the conditions that must be met if the exemption is to be claimed. In particular, 33 CFR 323.4(a)(6) lists mandatory BMP's for all roads. Since road construction is <u>not</u> part of the silvicultural exemption (33 CFR 323.4(a)(1)(iii)(B)), road construction and maintenance is simply under COE jurisdiction.

<u>NWP.</u> Projects that meet Nationwide Permit (NWP) conditions may be implemented whenever and wherever the need arises (33 CFR 330). The set of 40 NWP's cover numerous activities (i.e. road crossings or bank stability) thought to have minor effects. Since NWP's may be modified by the State, look for statements or requirements that reflect both the COE and the State (13).

With regard to the relationship between exemptions and general S404 permits, there are 2 important points: 1) general permit conditions are not less stringent than the road and trail BMP's, and 2) a General Permit can not be used to avoid doing the mandatory BMP's. The combination of mandatory BMP's and CWA S404(e)(1) general permits are expected to result in minimal separate and cumulative effects to the aquatic ecosystem (40 CFR 230.7). Permit notification requirements, conditions, limitations, and restrictions for nationwide permits, including road crossings and bank stability, are at 33 CFR 330. Conditions, such as erosion and silt control, apply to every permit (33 CFR 330 Appendix A).

Impairment. Stream health definitions, derived from EPA guidance (14), are combined with S404(b)(1) guidelines to address the question of "impairment." The assumption is that the exemption's "no impairment" criterion is satisfied if mandatory BMP's have been installed, that there is no loss of stream health class for more area or stream length than that allowed by applicable NWP's, and there has not been a determination of "significant degradation." Stream health will be discussed in detail later in this syllabus.

Complaints. Field operations that do not have a permit and do not meet S404 exemption criteria are subject to enforcement by either the COE or EPA (15). That means citizen action groups have 3 easy shots at agencies like the Forest Service, and 2 remedial shots if the first 3 fail. The first 3 shots would normally be done at the same time; these include formal complaints to the water quality management agency (FS for NFS lands), to the COE, and to EPA, stating that conditions are not in compliance with S404. Such complaints do not have to meet a particular format, nor do they have to be complicated. Telephone calls, letters, and/or photographs identifying location and condition is enough (16).

Since EPA has overall responsibility for S404, and if nothing happens and the complaint is not addressed, then the 4th shot is to take EPA into federal court under CWA S505 "Citizen Suits" for allegedly not enforcing S404 requirements. This step is formal and beyond this discussion; but the issue will revolve around permit conditions, mandatory BMP's, and stream health impacts.

The first 4 steps do not necessarily involve State law or enforcement; however, some States will take an active part on S404 issues because a determination of "significant degradation" is not likely to protect the state's designated uses, meet antidegradation tests, or satisfy S401 certification (13). Remember also that imposition of BMP's is required for any and all State designated uses (17). Therefore, the 5th shot would be to notify the state.

In summary, Exemptions and General Permits are valid if -- and only if -- the criteria and conditions are met. If they are not, then the data and analysis for an individual S404 permit is needed; 40 CFR 230 provides the criteria.

Related Pollution Prevention

To "satisfy mandatory BMP's and criteria for CWA S404 exemptions" (R-2 Water Quality Program (18)) also serves as the focus for Storm Water Permits required by CWA S402(p) (19) and "control opportunities" listed in "Water Resources Evaluation of Non-point Silvicultural Sources" (WRENSS) (20).

SWPPP. Storm Water Pollution Prevention Plans (SWPPP) are part of NPDES Storm Water Permits issued under CWA S402(p) for, among others, construction and industrial activities (40 CFR 122). Some States may also have procedural

requirements; but typically, SWPPP has 6 basic phases: 1) Site planning and design development; 2) Assessment; 3) Control measure selection and plan design; 4) Notification and approval; 5) Implementation; and 6) Final stability and close permit (21). Other than notification, the other steps are already necessary as a part of NEPA's mitigation section. So, if routine project design incorporates storm water pollution prevention plans (22); then compliance should be easy and the notification on project start and stop, a minor step.

WRENSS. The 1985 FS and EPA agreement acknowledges "Water Resources Evaluation of Non-point Silvicultural Sources" (WRENSS) as official guidance (23). While a detailed discussion is not appropriate here, the control opportunities serve as a bench mark of what is expected as part of routine FS operations such as timber sale logging plans. The grouping is by resource impact categories:

-- Aerial drift and application of chemicals
-- Bare soils.
-- Channel gradient change.
-- Compaction
-- Debris in channel.
-- Excess water.
-- Onsite chemical balance changes.
-- Slope configuration changes.
-- Stream shading changes.
-- Vegetative changes.
-- Water concentration.

Subpart H. Current experience suggests that laundry lists of "do-this do-that" usually obscures the objective. Simply put, there are many actions that can be taken to eliminate or minimize adverse effects and we need to be sensitive to the possibilities. What is particularly nice about the S404(b)(1) guidelines is the high level of common sense found in Subpart H "Actions to Minimize Adverse Effects" (40 CFR 230.70+). Subpart H is, of course, required reading, but, in summary, after you've done everything you can on pollution abatement and there still has to be a pollutant discharge, THEN:

-- Discharge at locations with the least damage.
-- Treat the material beforehand so it is benign.
-- Make sure the discharged material remains where it was placed.
-- Choose methods of dispersion that minimize pollutant drift.
-- Choose technology that is adapted to the site.
-- Use good procedures and enough trained people to do it right.
-- Avoid patterns of operations that disruption animal movement.
-- Avoid creating habitats conducive to undesirable species.
-- Avoid sites with unique or high value habitats.
-- Institute habitat development for a more desirable condition.
-- Avoid destruction of remnant natural sites in developed areas.
-- Minimize the effects on aesthetically pleasing features.
-- Avoid discharge sites that are incompatible with current human use.
-- Control runoff and erosion from fills.
-- Design dam water releases to accommodate fish and wildlife needs.
-- Compare the ecosystem lost to the one gained.

Best Management Practices -- General Comments

Taken together, these BMP's form a solid and realistic foundation for the antidegradation and "no impairment" standard. Note that these BMP's have substantial consequence: as they become fully implemented, they will modify

every aspect of resource planning, inventory, analysis, creating alternatives, mitigation, project administration, monitoring, and reporting.

Several of these BMP's depend on maps to show the relation of project activity to various features. Map scale and detail have to be sufficient for these determinations. For activities that impact wetlands or public water supply, scales of 1:10000 or less are typical, but since other agencies actually have jurisdiction, a pre-plan contact to determine what is necessary is a good idea.

For NEPA, project maps need to show detail on the water resource including: "waters of the U.S."; "special aquatic sites"; any aquatic and terrestrial TES critical habitat; public water supply intake areas; migratory waterfowl habitat; spawning habitat; National Wild and Scenic River segments; and land conditions such as heavy use sites, high hazard lands, roads and trails, or other major sediment and pollutant source areas that present a risk to the water system.

Timber sales sometimes present an interesting map, and perhaps, compliance problem. The Timber Sale Contract provision B6.5 is used to prohibit tractor roads and skidding down "protected streamcourses". The Timber Administration Handbook says "Streamcourses are streams, draws, washes, depressions, or other features shown as streamcourses <u>on the Sale Area Map</u>." (FSH 2409.15.0 8/3/92). Notice that unmapped streamcourses are <u>not</u> protected; which means that trivial criteria like map scale or lack of attention to detail could be dictating what is or is not being protected by the contract (24). Damage to "waters of the U.S." is the land owner's responsibility; without adequate streamcourse maps, the agency picks up liability for the logging activity. With regard to S404 exemptions, a map exercise by itself is not acceptable unless streamcourses are determined, or confirmed, by field examination (11 25 26); this step has to be done before the sale area map is completed.

<u>Monitoring BMP Effectiveness</u>

In 1985, the FS agreed to monitor baseline water quality and the effectiveness of BMP's (27). This creates a substantial need for methods that are comprehensive and integrate the various factors that drive the concentration and dispersal of pollutants. Since the S404 exemption for roads comes with a "no impairment" standard, monitoring also has to include stream health.

<u>CDA.</u> Several of these BMP's can be monitored using a "connected disturbed area" analysis. Connected disturbed area (CDA) is a measure of high runoff areas like roads, skid trails, mines, burns, or highly compacted soils that drain <u>directly</u> into the stream system. The CDA method, based on SCS hydrology (28), provides a strong foundation for analyzing land use, storm runoff, soil erosion, channel erosion, and sedimentation effects. Any increase in CDA, for example, will likely result in stream health damage, and therefore would make a good first approximation of Aquatic Ecosystem Cumulative Effects (40 CFR 230.11(g)) (29).

Current experience suggests that using CDA can improve monitoring reports in at least three ways: First, showing changes in CDA is more comprehensive, faster, and easier than tracking each individual practice. Second, CDA can report on positive and pro-active management; not just failures. For example, early operations that help "disconnect" CDA from the stream system are some of the most cost effective and beneficial measures that can be applied; and credit needs to be given for the action. Third, CDA answers the "how much is enough" question; for example, when CDA = 0, further effort probably has little value.

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Still with us? This legal stuff can turn your head into mush; and since you might need it later, take a break and don't let old chaos get to you.

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Chaotic Cloverleafs

The water quality laws and regs are like a hugh highway cloverleaf that federal, state, and local agencies have been building since 1948: roads go everywhere; coordination not always great; and traffic control written in latin.

On top of this cloverleaf, we now overlay "best management practices" including those written by COE for roads and trails, those by the State for S208 or S319, those by EPA for storm water, and those by the FS as "conservation practices" and "standards and guidelines." The complexity, not to mention bookkeeping, is bewildering. So T-Walk, with an eye on the water, tiptoes through the maze and just grabs onto those BMP's that support the S404 "no impairment" standard.

The value of this approach is that S404 COE BMP's provide a framework for which other sources can integrate scope and content. Each BMP description includes an overall perspective, special terms, information needed on the project area map, pertinent design criteria, minimum monitoring criteria, and possible remedial steps. Because of T-Walk's field orientation, not much attention was given to planning related BMP's or those that could not be effectively monitored.

Specific Best Management Practices

>>>> 1 limit road & trail system to the minimum feasible number, width, and total length consistent with the specific operations, topography, and climate;

Perspective: Use good planning to stay out of the "waters of the U.S." Where that is not possible, then minimize the road and trail system that contributes runoff and sediment to the stream system. Field operations need to implement what the plan says, including any descriptive instructions such as skid trail spacing. Failure to either plan or implement a plan, puts the burden of showing that the actual random road and trail pattern is somehow the "minimum feasible" and thus not subject to S404 enforcement action or the costs of restoration.

Vehicle speed and safety factors, like sight distance, on roads constructed in rolling or mountainous topography result in road widths that vary considerably and yet are easily justified as "minimums". This BMP does not interfere with good transportation engineering or good road maintenance practices (30). However, there are many extra-wide spots that just happen, that do not satisfy the "minimum" test, and depending on stream damage, could be enforcement issues.

Some stream damage and enforcement issues are easy to avoid. For example, the construction of outside curves doesn't have to result in pushing the side-cast material off into the stream system; it can often be placed in less vulnerable spots with minor, if any, additional cost. Similarly, side-cast material from routine road maintenance and snow plow operations can be located to favor sites with a vegetative buffer and avoid dumping directly into the stream system.

Special Terms: "minimum feasible" means to reduce levels of pollution to the maximum extent practicable (S 319(a)(1)(C)); and "practicable" means "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" 40 CFR 230.3(q).

Project Area Map: For each alternative: show proposed permanent and temporary road system. Summarize the extent of proposed activity in areas of moderate and high risk, difficult revegetation, or on side slopes over 50%.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Any management induced factors, either in combination or as individuals, that render debris avalanche, debris flow, or earthflow risk greater than "low" will be fully mitigated. This may result in new alternatives or extraordinary mitigation to insure slope stability and avoid long term stream health damage.

WRENSS Tables V.5, V.6, and V.7 (pg V.26-36) show steps for project evaluation; factors associated with "low" risk can be paraphrased as follows:

- Very few roads and skidways on slopes over 50%.
- Road and skidway density less than 8% of the area.
- Full bench roads on slopes over 50%.
- Most road locations or construction sites limited to ridgetops, stable lower slopes, or alluvial valley floors.
- Ridgetop roads constructed with minimum fills.
- Road cross drains designed for a 10 year storm or greater.
- Road and skidway cross drains designed to disperse flow into vegetative buffers.
- Road and skidway cross drains designed to minimize rather than concentrate flow.
- Permanent and temporary road stream crossings and associated facilities such as overflows will not wash out or fail at expected flood flows.
- No roads and skidways on slopes >70%.
- Areas with identifiable landslides or mass failure have been avoided.
- No storm water diverted or concentrated on unstable areas.
- Fills below culvert outfalls or cross drains are protected.
- Fills are properly compacted.
- Fills do not bury or incorporate organic debris.
- Soils are of variable textures with no large areas of clayey soils.
- No evidence of restricted infiltration or subsurface drainage.

Monitoring: Miles of road and trail failing to meet "low" risk criteria. CDA plan compared to CDA actual. Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

Existing roads on medium and high risk areas would be good candidates for road obliteration; technical manuals for slope stability are available (31).

>>>> 2 except at crossings, all roads and trails* shall be located sufficiently far from streams or other water bodies to minimize discharges;

Perspective: Standard applies to all roads and trails. The "and trails*" comes from S304 guidelines used to develop S208 BMP's; these are mandatory as a part of S404 (10). Forest Service timber sale contract provision, B6.5, prohibits wheeled and track-laying equipment use in "protected streamcourses".

Sedimentation of 0.3 cubic foot per road acre per year has been achieved with common BMP's for road locations, vegetative buffers, and closely spaced rolling dips. The value comes from the Deadhorse watershed (Fraser Experimental Forest) and reflects some of the more difficult logging terrain in R-2; this is an appropriate "minimum discharge value" for similar conditions (32).

There is a trade-off here; road locations that avoid "waters" or maximize the use of vegetative buffers at discharge points for waterbars, culverts, or other drainage features will likely be less expensive than roads that rely on on-site erosion and constructed sedimen ntrol to meet exemption requirements.

Project Area Map: Pay particul tention to all roads and trails in the proximity of sites which must be ded such as "special aquatic sites".

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Use vegetative buffers and sediment traps to disconnect CDA from the stream system. The vegetative buffer equation, **Vbfr**, (discussed in detail later) has been validated for several major geologies in R-2. The equation calculates the minimum distance needed to protect streams from road and trail erosion.

Monitoring: CDA. Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

Disconnect disturbed areas by adding cross drains or by increasing the effectiveness of the buffer such as adding large woody debris or installing sediment pits. Reduce disturbed area by accelerating revegetation efforts.

>>>> 3 crossings shall not restrict the passage of expected floods flows;

Perspective: The COE District Engineers have authority to define "expected flows" for application of S404 requirements in their areas (33). Design storm criteria vary somewhat so a little checking is worthwhile. Current advice is to use 10 year flood flows for temporary facilities and 100 year flood flows for permanent facilities (34). Typical crossings such as fords, low water, culverts, or bridges are all suitable choices; however, the facility must be built to remain stable under the expected flow regime.

Special Terms: expected flood flow is a statistic or probability statement; for example, a 10 year flood is expected to occur once in 10 years.

Project Area Map: Show road and trail crossings. Note crossings that require S404 NWP 14 permits (as opposed to crossings covered by the exemption).

Design Criteria: Use 10 year flood events for temporary and 100 year flood event for permanent facilities and meet all NWP 14 "Road Crossing" conditions. For lesser designs, contact the COE for approval (34 35).

Monitoring: COE sanctioned design flow compared to final installation; all permit conditions, including site stability, are met.

Remedial: Meet exemption/permit conditions. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 4 fills shall be stabilized during & after construction to prevent erosion;

Perspective: Standards are derived from the Storm Water Permit requirements in CWA S402(p). Storm Water Permits may not always be required but the regulatory material and EPA handbooks are good sources for pollution prevention planning and erosion and sediment control techniques (36). Each state may operate their own permit program or leave it up to EPA; but in either case, the standard is "no impairment" and EPA's technical material is the foundation.

The incentive for slope stability and erosion control is to reduce the burden on maintaining sediment control facilities -- or if there is a failure -- from stream health restoration. This standard also applies to road maintenance and re-construction to provide stability under flood flow conditions.

Project Area Map: Scale and detail is defined by SWPPP.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H). Review NWP 14 for requirements for fills at road crossings (33 CFR 330).

WRENSS factors associated with "low" risk fills are noted as follows:

- Very few roads and skidways on slopes over 50%.
- Full bench roads on slopes over 50%.
- Ridgetop roads constructed with minimum fills.
- Road cross drains designed for a 10 year storm or greater.

- -- Cross drains designed to disperse flow into vegetative buffers.
- -- Cross drains designed to minimize rather than concentrate flow.
- -- Fills and overflows will not wash out or fail at expected flood flows.
- -- No storm water diverted or concentrated on unstable areas.
- -- Fills below culvert outfalls or cross drains are protected.
- -- Fills are properly compacted.
- -- Fills do not bury or incorporate organic debris.

Slope stability, erosion control, and sediment control will be designed for the 10 year 24 hour storm or snow melt equivalent (37).

Design temporary crossings to be stable under the 10 year flood event and design permanent crossings to be stable under the 100 year flood event (34).

Monitoring: CDA. Fill stability (local criteria). Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Harden road and trail crossings to meet stability requirements. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 5 minimize equipment disturbance in "waters" outside construction zone;

Perspective: This is primarily a planning step, followed with necessary field inspection to insist on protected areas. Areas within "waters" often include the most productive as well as some of the most vulnerable soils. Because these soils tend to be more moist, they are often easily damaged by equipment use. The basic direction is to stay out -- or pick a time, place, and method that reduces the risk of soil damage or changing the drainage and flow patterns.

Good planning, together with protection for stream bank vegetation, a supply of woody debris, shade for the stream, and a low-erosion risk road and trail layout, should result in meeting the "no impairment" standard.

Project Area Map: SWPPP scale & detail; show areas not to be disturbed.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Monitoring: CDA. Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 6 minimize vegetative disturbance in "waters" during and after construction;

Perspective: This is primarily a planning step, followed by field inspection to insist on protected areas. As part of a larger construction activity, standards are derived from the Storm Water Permit requirements in CWA S402(p). Because these soils tend to be more moist, they are often easily damaged by equipment use. The basic direction is to stay out -- or pick a time, place, and method that reduces the risk of soil damage or changing the drainage and flow patterns.

Good planning, together with protection for stream bank vegetation, a supply of woody debris, shade for the stream, and a low-erosion risk road and trail layout, should result in meeting the "no impairment" standard.

Project Area Map: SWPPP scale & detail; show areas not to be disturbed.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Monitoring: CDA. Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 7 road crossings shall not disrupt the movement of resident aquatic species;

Perspective: Culverts concentrate high flow and increases its depth and velocity to a maximum just before it is spilled on to the stream bed. It is not uncommon to create scour pools just below outlets and, if the water velocity or drop is sufficient, create a migration problem. This standard applies to all roads, including those constructed before 1975, so there is a need to check all culverts for migration problems. Such an inventory of problem crossings could then become part of road maintenance and re-contruction planning.

Design Criteria: Determine pre-project stream conditions that influence migration at the site. Comply with NWP 14 conditions.

Design to insure that final bed stability and elevation will satisfy migration requirements. Bridges, arch pipe, or wide culverts may be needed if culverts laid on grade will scour out bed material during expected high flow (38).

Monitoring: Fisheries migration criteria satisfied (40 CFR 230.23 & .31).

Remedial: Use control opportunities in Subpart H. Actual loss of migration will be repaired to pre-project conditions. This may include replacing with wider culverts, resetting to grade, rebuilding stream approaches, or modifying existing culverts, such as cutting out part of the culvert bottom.

>>>> 8 take borrow material from upland sources whenever feasible;

Perspective: Standards are derived from the Storm Water permit requirements in CWA S 402(p). If you can stay out of the "waters of the U.S." and fully buffer project disturbance, this would make Storm Water permits either unnecessary or much simplier to plan, administer, and comply.

Special Terms: feasible -- see note under #1 "limit road and trail...."

Project Area Map: SWPPP scale & detail; show borrow areas.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Monitoring: CDA. Stream health.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 9 the discharge shall not take, or jeopardize the continued existence of, a T&E species, or adversely modify or destroy critical habitat;

Perspective: This is primarily a planning step, followed with necessary field inspection to insist on protected areas.

Special Terms: Endangered and threatened wildlife and plant species are listed in F&WS 50 CFR 17.11 and 17.12. Critical habitat refers to areas designated as critical habitat in 50 CFR 17 or 226 (marine list) (50 CFR 402.02).

Project Area Map: SWPPP scale & detail; show areas that will be disturbed and field validate critical habitat.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

Prepare a list of likely species and critical habitat characteristics. Test activity for mitigation requirements at 25, 50, and 100 year storm events, wind, fire, and other low probability events for vulnerability.

Extraordinary mitigation will be incorporated in all site plans including sediment pits in conjunction with fully adequate vegetative buffers and stepped up time tables for complete erosion control.

Monitoring: CDA. Stream health (target species 40 CFR 230 and 50 CFR 17).

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 10 avoid discharges into migratory waterfowl habitat, spawning areas, and special aquatic sites [40 CFR 230.10(a)(3)]; special aquatic sites include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, and riffle and pool complexes. [40 CFR 230.3(q-1)].

>>>> 11 discharge shall avoid areas in or near public water supply intake;

>>>> 12 discharge shall avoid areas of concentrated shell fish production;

>>>> 13 discharge shall avoid National Wild and Scenic River System reaches;

Perspective: This is primarily a planning step, followed with necessary field inspection to ensure protection. The Storm Water Pollution Prevention Plan required under CWA S 402(p) requires the site map to show areas that will not be disturbed. If practical alternatives exist; alternatives that do not involve special aquatic sties are presumed to be available, unless proven otherwise [40 CFR 230.10(a)(3)]. However, activities already permitted by S404 NWP and State 401 Certification may be implemented without further review.

FSM 2542 lists the municipal watersheds and other special sites are normally identified in the Forest Plan.

Special Terms: Special aquatic sites include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, and riffle and pool complexes. These sites make significant contributions to the general health and vitality of the entire ecosystem for a region because of their productivity, habitat, wildlife protection, or other important ecological characteristics [40 CFR 230.3(q-1)].

Public water supply is 15 connections or 25 people (42 USC 300f).
National Wild and Scenic River System -- designated and study. 16 USC 1271-87.

Project Area Map: SWPPP scale & detail; show areas that will not be disturbed.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0) with particular attention to special aquatic sites, spawning areas, public water supplies, and protected rivers. Reduce stream damage risk (Subpart H) with particular attention to special aquatic sites and public water supplies.

Prepare a list of likely sites that are or would be affected by project action; test activity for mitigation requirements at 25, 50, and 100 year storm events, wind, fire, and other low probability events for vulnerability.

Extraordinary mitigation will be incorporated in all site plans including sediment pits in conjunction with fully adequate vegetative buffers and accelerated time tables for complete erosion control.

Monitoring: CDA. State drinking water standards in public and private water supplies. Stream health for target sites.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> 14 discharge material will be free from toxic pollutants in toxic amounts;

Perspective: Standards are derived from the Storm Water Permit requirements in S402(p). The EPA handbooks for both construction and industrial sources are good sources for pollution prevention and control of toxic materials (39).

Special Terms: defined by 40 CFR 122.

Project Area Map: SWPPP scale & detail. Locate source areas of natural as well as human caused contamination and determine the degree of risk.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS as a foundation to fully control toxic contamination of the stream system. Reduce stream damage risk (Subpart H).

Remedial: Use SWPPP and WRENSS as a basis of mitigation to eliminate toxic contamination. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sedimentation has resulted in toxic contamination, remedial action will include removal and proper storage of toxic deposits.

>>>> 15 all temporary fills will be removed and restored to original elevation.

Perspective: Many so-called "temporary" roads and trails are merely abandoned; but the exemption requires that the effects, as well as the use, remain temporary. This rarely happens when roads and trails are used, then abandoned.

Returning temporary fill sites to original elevation and contour is a key element in closing out activities. The final inspection has to insure that the drainage will function as well as it did before the fill was introduced. If it does not, damage to stream health is likely.

Project Area Map: SWPPP scale & detail. Locate all temporary crossings.

Project Area Map: Scale and detail is defined by Pollution Prevention Plan. If the project is part of a timber sale contract, all "waters of the U.S." need to be mapped for streamcourse protection under B6.5.

Design Criteria: Determine pre-project stream health (40 CFR 230). Use SWPPP & WRENSS to minimize CDA (Goal: CDA = 0). Reduce stream damage risk (Subpart H).

This is part of transportation and contingency planning. Design fills to pass and be stable for at least the 10 year flood event. When the temporary fill is removed, return the channel gradient to what it was originally, backslope the banks, and re-establish vegetation. Waterbar the contributing sections of road to insure that storm water is not running over the new work.

Remedial: Use SWPPP and WRENSS to reduce and disconnect CDA from the stream system. Unless Permitted, actual stream damage will be repaired to pre-project conditions. If sediments have reduced habitat diversity or productivity, action will include sediment removal such as by channel traps or by suction dredge.

>>>> STREAM REACH REVIEW - Clean Water Act Monitoring

A stream reach is a field unit large enough to get valuable information yet small enough to do with reasonable cost. A reach is a good integrator of physical, chemical, and biological factors including energy and transport capability; it needs to be representative of the streams under study.

>>>> Thalweg Walk (T-Walk) Advance Warning System Procedures

The focus is on the thalweg position. The monitoring and evaluation perspective is from the stream to the land, rather than from the land to the stream. The value of such a perspective is that it is easier to see stream bed and bank conditions and the need for stream health.

>>>> (Field manual - effective use requires prior training.)

The 5x8" field manual is not an instruction book. Its' purpose is to consolidate figures, tables, and definitions that are hard to remember or aid field review and interpretation (3).

>>>> **Perspective**

>>>> Diversity, productivity, and stability are compared to long term natural conditions.

Under the Clean Water Act, biological integrity has 3 primary dimensions: diversity, ecosystem stability, and productivity. Sooner or later, all aspects of land management will be measured against these dimensions in a legal setting: has diversity been reduced? has ecosystem stability been reduced? has productivity been reduced?

T-Walk assumes that the best approach is to define field conditions that integrate wet and dry climate cycles with site characteristics. Then make the comparison to pristine and stable biosphere conditions. The evaluation itself will not be easy because there has been no past systematic effort to keep watershed information together in a way that aids field review and experience. Correspondingly, there is a need to create long duration open file, watershed folio, as a depository for such material as maps, photos, field data, and analyses suitable for long term definition of watershed conditions (40 41 42).

>>>> Desired health is reflected by the greatest standing crop and greatest niche partitioning.

This definition of desired health maintains both a high level of productivity, maximum flexibility for resource use, and potentially the best strategy for long term economic stability as developed in the legislative history. It is also likely to be the best support for rare and endangered species.

>>>> For advance warning purposes, the aquatic macroinvertebrate community is the best place to look for early signs of stress; many species are sensitive to pollution and respond quickly to it; bottom fauna tend to have complex life cycles and die off if conditions are outside tolerance limits; and many species have an attached or sessile form and cannot migrate to avoid the stress.

Simple monitoring can help detect problems while they are still small. For example, a beginning decrease in aquatic insect production from sedimentation may be easy to correct with simple erosion control measures. But, get to it. It is a lot cheaper to fix problems while they are still small.

>>>> Recovery depends on type of impact. Non-selective physical impacts tend to leave adequate gene pools and revitalization of health will proceed rapidly upon removal of the stress condition. Recovery from selective chemical impacts requires an improved physiochemical environment and, perhaps, rebuilding an adequate gene pool.

Restoration of physical conditions requires a different approach than does restoration of chemical integrity. It is important to identify limiting factors so initial restoration efforts can actually start the recovery process (43). If in doubt, start by looking at a biological response curve to determine how much has to be fixed to get the necessary response. For example, if an existing mine drainage yields 2.0 mg/l of zinc and proposed treatment will remove 1.8 mg/l, then biological response should be expected only if the target species can re-colonize and survive the remaining 0.2 mg/l; otherwise, there is no response.

>>>> **Focus** - To fix existing & potential problems while they are still small. Restoration costs run about 20 times the ordinary prevention costs.

The early fix is cheaper: unblock a plugged culvert or replace a road crossing; construct an armored stream ford or repair 50 feet of bank collapse; install county construction Best Management Practices or lose a lake fisheries and reduce residential property value; or enforce contract soil erosion control requirements or take sand out of the stream with a suction dredge (41 44 45).

The liability for problems is also multi-resource in the sense that damage caused by one resource use creates a burden for all resource users. For example, stream sedimentation caused by erosion from uncontrolled off-road vehicles may be enough to require extra and costly mitigation in a nearby timber harvest.

>>>> Purpose: Advance Warning of existing or potential impacts on stream health.

The value of an advance warning system is to get on top of the problems before they have a chance to accelerate and to identify any additional monitoring and/or remedial effort. The best use is to pat backs and give awards for good administration and trouble-free contract work. But, it can also be used to document, plan, and implement restoration efforts.

>>>> Notification & documentation of CWA related issues:

>>>> 1. summary of land use & BMP impacts on CWA water quality;

The legal framework makes land use impact analysis and damage control more and more a part of doing business. The purpose in T-Walk is to provide a concise format for documenting land use activities and associated water quality impacts.

>>>> 2. summary of current and future (2 year) stream health;

Stream health assessments allow the manager to routinely contribute to the State's biennial 319 Water Quality Assessment Report. Management benefits also from the effort to prioritize planning, surveys, and restoration efforts.

The fact that current stream health is Robust does not guarantee that such health will remain. The value of identifying a 2 year trend is that management adjustments can be more easily installed and avoid harsh adjustment later.

>>>> 3. expected restoration costs to recover Robust Stream Health;

This is not a trivial exercise; the State water quality agency becomes a strong silent partner in project planning and operation if an impaired watershed is involved. Under normal circumstances, project installation costs already include the management control to prevent damage. Failure to do so, creates needless restoration costs and management disruption.

>>>> 4. a quick fix remedial action plan

Cheaper, cheaper, cheaper. The value of any remedial plan is to correct problems as soon as possible. Costs escalate exponentially as time drags on. At least take care of any emergency and high risk situations.

>>>> ... and follow up monitoring plan;

What is the risk? Match the monitoring requirements to project schedules and the associated risks. Monitoring need not be complicated. A quick walk-through or a windshield survey may be adequate; but whatever, write it down so it can be summarized for a land use monitoring plan. The need for more complicated multi-year monitoring can also be noted for the budget process.

>>>> 5. documentation of field observations.

Program control runs on documentation. And we know it is important, but the reality suggests that field forms are often treated with less than professional quality. Be aware that compliance to the Clean Water Act is a legal issue and that sloppy, incomplete, or illegible records are of no value. T-Walk was built to "enhance" the technician's ability to document and synthesize pertinent field information into conclusions about stream health, restoration, and monitoring.

>>>> Equipmt: Waders, 5x hand level, T-Stick, survey rod, 5-10x hand lens, 100' measure, insect repellent, M+calc, % clinometer, map, pins, C/F thermometer, trowel, snooper, cord & line level. Optional: Camera, mm ruler.

The job is more likely to get done if the equipment is hassle free. If your bag is water quality, then a water quality bag is a good idea. Get one big enough to hold the loose stuff. However, always keep any camera equipment, film, and name board in a separate bag to prevent loss and damage.

Your day will be a lot more enjoyable, if your waders fit, have a felt sole, and keep your feet warm. Normally, hip waders are enough for low flow surveys.

For water surface slopes, a regular tripod and engineer level is most accurate. However, T-Walk does not require super accuracy and several simple methods will work well: 5x hand level or cord and line level. But do NOT use an abney or clinometer for water surface slope.

- Read a survey rod with a 5 power hand level supported by a T-Stick; good to about 70'. Survey rods that fold up or roll up are readily available.
- Carry 50'+ of 135+lb test nylon braided mason's cord in a chalk line reel and a carpenters line level. (Rewind the chalk line reel with the masonry cord). At site, anchor the line near the water line, pull tight, level, and measure the distance to the water surface. Then measure off a distance downstream, pull the line tight, level, and measure the drop to the water line. Calculate the % slope from the distance and difference in drop.
  Before the field season, pull the cord tight, mark the 25' and 50' distance with indelible pen, and verify the accuracy of the line level. It takes at least 8 lbs tension to take the sag out of the cord, so pull hard.

For most field applications, a folding or roll-up rod (i.e. 6' Keson Pocket Rod) is a more convenient choice than the typical 3 piece, oval fiber glass rod. An inexpensive pocket hand lens of 5 or so power is necessary to look at bugs. A 100'+ fiber glass tape or range finder is usually sufficient for distances.

All T-Walk calculations can be done with a simple memory plus calculator. Try the M+ key to count hits during pace transects while you keep total paces. Use the % clinometer for road grades and side hill slopes. Use USGS 1:24000 topog maps for watershed area and elevation. (And perhaps, to keep from getting lost).

Survey pins or 7" gutter nails are useful for holding tapes or cords or for marking features for photographs. An aluminum cased thermometer is fairly inexpensive and less likely to get broken. A small flat digging trowel (like a

6" throw-away tile cement spreader with a 1/4" notch) is easy to carry and cuts easily through the litter layer.

For most situations you need a "snooper" to see the stream bed. If the water is clear, then a flat, 8x10", clear plastic sheet placed at water surface works well. However, if the water is murky, then you need a way to lower the "window" toward the substrate -- such as with a "super snooper" which is a 3'x4" plastic tube with a clear plastic bottom (46). Any tubelike affair with a clear bottom would work: a 2" or 3" rain pvc downspout cut to length for backpacking or a tall, clear, acrylic "vase" from a hobby store.

Make a stout 5' T-Stick from 1x1" hardwood and use it when stream walking. Mark the stream depth categories (Sharpie black) for the depth tally. Mark (or glue) a 1/10' scale on one full side. If you plan on pictures, paint one side with alternating colors (1' orange and white) and use it for a photo scale. Add a flat piece of plexiglas and binder clips to hold the forms. If your eye level is shorter than 5', mount the form board at your eye level so the T-Stick can still be used as the hand level support.

Optional equipment is whatever you want to take along. For pebble counts you need a millimeter ruler. If you plan to use a camera, spent a little study time on how to get good photographic evidence so you actually make the point you want to make. That is not as easy as it sounds; current experience suggests that typical "point and click" photos have very little, if any, value in a judicial setting (47). The acrostic "FIELDSCRIPT" suggests some ways to get better field photographs; check the glossary for details:

Flash fill-in	Identify time & place	Evidence of what?
Light & sun angle	Depth of field	Scale included
Color balance	Reproduction & process	Indexing
Protection for years	Text	

Be sure to include a name board or steno pad for date and location. If time is short, consider using Polaroid prints. The new color copiers do a good job on color prints; but if one is not available, black and white is satisfactory. Water surface glare can be reduced with a polarized lens.

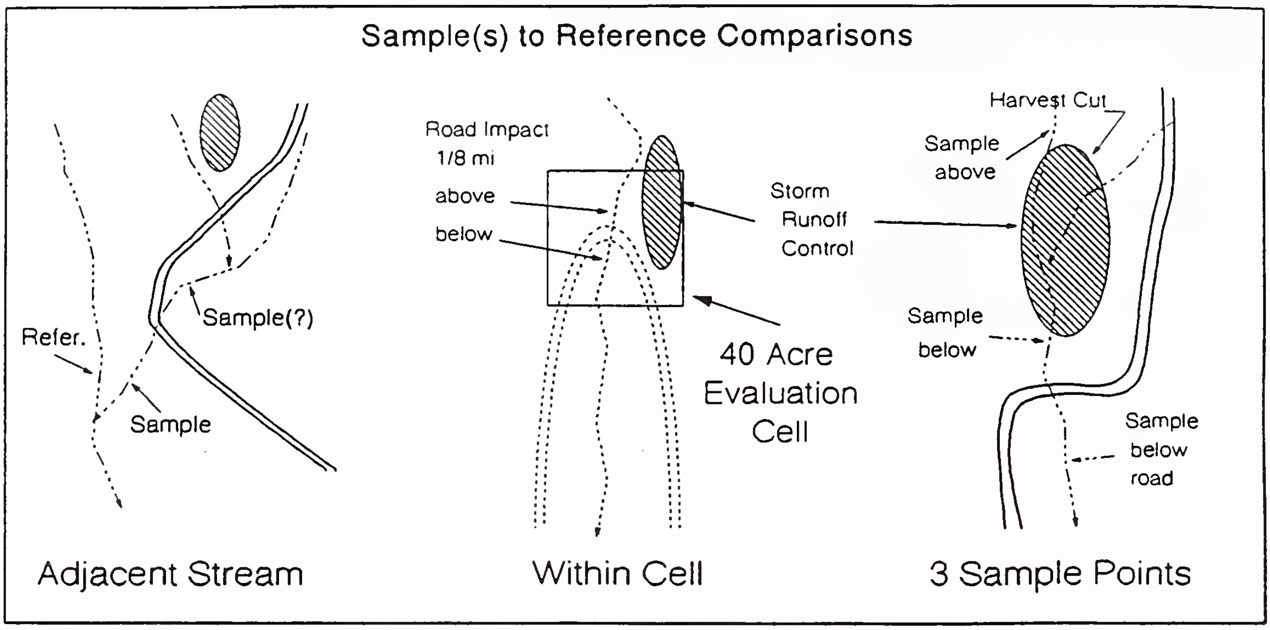
>>>> **Scale for Impact Analysis** -

>>>> Ideally, center a 40 acre evaluation cell on the major intersection of the management activity and the stream.

The size of a 40 acre evaluation cell is the right order of magnitude for road evaluations and field investigations of land use activity. It is small enough to do and large enough to incorporate the range in most land use impacts. The cell layout is flexible; please adjust to make the best use of your time.

>>>> This divides into two 1/8 mile (660') stream reaches and allows the above reach to be compared to the below reach for an estimate of impact. In field use, reaches may be longer or shorter and should be located to get the best information.

The focus here is on comparisons. The Clean Water Act insists upon comparisons made against a long term naturally working and functional stream as a reference. Comparisons of "above to below" or "before to after" conditions are pretty common. When the "above" conditions do not reflect the same physical or chemical conditions as the "below" site, or the "before" conditions were never measured, you will need to use an off-site reference to serve as a surrogate.



However, do not hesitate to make use of your field experience and on-site judgement to assign the necessary reference conditions. For example, if there had been a road culvert washout, the conditions of impact can be inferred by the difference in color and chroma of the old substrate as compared with the brightness of the new deposits (48). Similarly, probing through the fresh fill material will help quantify how much material has to be removed to restore the original pool depths (49).

>>>> This manual follows the normal steps used for site analysis: begin with road & upland conditions, track the effects into the stream, & estimate current & future stream health, restoration, and follow-up monitoring.

T-Walk is conceptualized as an incremental process in which you do as much as needed to get the answers. In most situations, start with a watershed risk and damage control perspective to find out where best to do T-Walk. After reaches have been selected, then work through field stream health assessments. The approach, as carried into the field, is still to progress from cause to effect. This appears to be reasonably efficient because most watershed damage is obvious and remedial action easily documented.

>>>> Stream Health - The purpose of T-Walk is to determine Stream Health for each stream based on its own capability defined in terms of diversity, stability, & productivity. The Stream Health evaluation strives to answer three questions:

What is it now?
What should it be?
What has to be fixed?

There are two scales to Stream Health: the first, called Aquatic Life Health, is concerned with diversity and stability; and the second, with productivity.

Aquatic Life Health (diversity and stability) uses an EPA classification (50). The approach combines community structure and trophic changes with the idea that healthy ecosystems tend to have all niches fully occupied by appropriate species, that no species become extinct, and none reach epidemic proportions for long enough to destroy the niches of other species (51).

Aquatic Life Health has six classes: Robust, Adequate, Diminished, Impaired, Precarious, and Catastrophic. The first, Robust, is used as the standard for the diversity scale and the other classes are defined as incremental changes.

Robust	Comparable to the best situations unaltered by man; all regionally expected species for the habitat and water body size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Adequate	Fish and macroinvertebrate species richness somewhat less than the best expected situation, especially due to loss of most intolerant forms; some fish species with sub- optimal size distributions or abundances; trophic structure shows some sign of stress.
Diminished	Fewer intolerant forms of fish and macroinvertebrates are present. Trophic structure of the fish community is more skewed toward an increasing frequency of omnivores; older age classes of top carnivores may be rare.
Impaired	Fish community is dominated by omnivores; pollution tolerant forms & habitat generalists; growth rates and condition factors commonly depressed; few top carnivores; hybrids and diseased individuals may be present. Pollution tolerant macroinvertebrates are often abundant.
Precarious	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, physical damage, and other anomalies regular. Only tolerant forms of macroinvertebrates are present.
Catastrophic	No fish, very tolerant macroinvertebrates, or no aquatic life. Ecological upset and collapse; retrogression.

The evaluation of productivity starts with ecological carrying capacity as: "the number (or weight) of organisms of a given species and quality that can survive in, without causing deterioration of, a given ecosystem through the least favorable environmental conditions that occur within a stated interval of time" (52).

The numerical thresholds for six production classes are based upon long term natural conditions. Production changes are indexed on a ratio scale of 0 to 1 calculated as projected (or existing) divided by expected production under long term natural - **Reference** - conditions. By using a ratio, many different units of measure are applicable. The terms are commensurate, the ratio dimensionless, and "1" is the best ratio. The production ratios are:

Robust	production	ratio	range:	1.0 to 0.9	of Reference	Condition.
Adequate*	"	"	"	<0.9 to 0.7	"	"
Diminished	"	"	"	<0.9 to 0.7	"	"
Impaired	"	"	"	<0.7 to 0.5	"	"
Precarious	"	"	"	<0.5 to 0.3	"	"
Catastrophic	"	"	"	<0.3 to 0	"	"

Stream Health (table) is a combination of the Aquatic Life Health class and production. Stream Health is determined by the lowest of the two scales. This improves our ability to determine what the limiting factors are, so further damage can be prevented and restoration planned.

The Clean Water Act goal: "to protect the physical, chemical, and biological integrity of the nation's water" sets the standard for Robust Stream Health.

Stream Health Classes

(Combination of aquatic life health and carrying capacity ratios)

Aquatic Life Health Class	Ecological Carrying Capacity Ratios 1.0-0.9	<.9-0.7	<.9-0.7	<.7-0.5	<.5-0.3	<.3
Robust	ROBUST	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Adequate	ADEQUATE*	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Diminished	Diminishd	---------->	---------->	Impaired	Precarious	Catastrph
Impaired	Impaired	---------->	---------->	---------->	Precarious	Catastrph
Precarious	Precarious	---------->	---------->	---------->	---------->	Catastrph
Catastrophic	Catastrph	---------->	---------->	---------->	---------->	---------->

* Adequate only applies to legally impacted stream reaches.

Habitat Conditions

Recall that in the discussion on antidegradation, four basic points were made: 1) physical habitat deterioration is just as much of a part of antidegradation as is chemical pollution; 2) physical habitat is present is all situations; 3) if the biological system has not been overwhelmed by chemical pollution, then

physical habitat conditions set the limiting factors and the antidegradation floor; and 4) the ability of substrate, cover, flow, depth, pools, and riffles to support existing aquatic life is a key evaluation.

Reduced habitat complexity and the loss of pool depth tends to truncate diversity of both species and age classes in a system; this often results in systems with a few species, limited age classes, and reduced carrying capacity. Changes in habitat are often the result of watershed conditions and the corresponding effect on runoff volumes and peaks, changes in bank stability, changes in sediment supply, changes in the amount and structure of large woody debris available to the stream, and changes in energy relationships (i.e. water temperature, snowmelt, and freezing. (53 54).

For many forest systems, large woody debris and treeroots provide major structural control in streams. Large amounts of material tend to produce stream features with numerous, small distorted pools, short step-like riffles, multiple channels, backwaters, ponds, and combinations of slack and plunge pools associated with large embedded pieces. (55).

In channels that have not been blown out, fisheries cover is provided by small and large woody debris, rootwads, undercut banks, and deep water. Stable material increases channel complexity by its influence on the distribution patterns of velocity, bars, and pools as well as the distribution and retention of organic matter. Pools and undercut banks created by stable boles or rootwads can be up to 10 times more productive than similar, but unstable, sites. (56)

In winter, fish abundance and winter survival is often limited by the amount and condition of microhabitats and overhead cover associated with large woody debris and treeroots. During high flows, stable material provides protection from peak flow velocities and during low flows provides cover and maintains the pool depths needed for survival. (57).

In blown out channels, cover consists of rocks, boulders, and surface turbulence. Loss of stable instream large woody debris reduces channel structure and complexity, reduces total number of pools and pool volume, releases large amounts of previously stored sediment, and reduces the system capacity to store and process organic matter. Unstable debris tends to create large, but infrequent, jams and piles. (58)

Streams that have been damaged in the past can often be improved by the addition and proper placement of large woody debris as a means to provide cover (extra depth, preferred substrates, stable stream structure, overhead cover, etc). Good design includes proper size distribution, spacing, and hydraulic stability during high flows (59).

The T-Walk Stream Health interpretation starts from the evaluation of limiting factors or habitat conditions needed to support local species of trout (43 60). Current experience suggests that most routine land use activities tend to create physical changes and soil disturbance rather than chemical impacts, so T-Walk uses only a simple screen to see if there might be a chemical problem. If there is a chemical problem, then other monitoring techniques, not discussed here, are more appropriate (29 61 62).

>>>> Storm Runoff Control -

This is specifically mentioned by the legislative history. Storm runoff is the driving force behind pollution from many land use activities. Sediments, organics, nutrients, salts, biocides, fugitive metals, and even heat loads may be carried into stream systems by storm runoff. Runoff has the erosive power to make long term changes in land surface drainage by creating rills and gullies. To control or improve water quality hinges on the effectiveness of soil and water management practices to provide storm runoff control.

This big issue needs to focus on good, long term planning as well as the actual field implementation. Poorly planned or random layout and pioneering just leads to rebuilding, lost time, higher total costs, and increased erosion.

The role of soil and water conservation practices is to decrease soil erosion, runoff volume, and peak flows. Concentrate on these two questions:

What vegetation and erosion control practices will be used?
What sedimentation control practices will be used?

Under CWA S404, the Corps of Engineers regulates dredge or fill activities, and any related (or secondary) discharges, in one of three ways: by exemption, by a general permit, or by an individual permit. There are specific regulatory criteria that must be satisfied for each of these applications to be valid.

Cumulative effects are part of the test. Both the exemption and the general permit **require** that cumulative effects **remain** minor and insignificant. If the cumulative effects are not minor and insignificant, then the exemption and the general permit are not valid and an individual S 404 permit is needed.

The exemption for permanent and temporary roads and trails (including skid trails) is based on the application of **mandatory** best management practices and their effectiveness. The standard of measure is to minimize adverse impacts to the aquatic environment:

1) that flow and circulation patterns are not impaired;
2) that chemical and biological characteristics are not impaired; and
3) that the reach has not been shortened. (CWA S 404(f)(1)(E)).

To claim the exemption, the criteria must be met. If they are not met, the activity is not exempt and permits must be obtained. Sometimes a general permit may be applicable; however, be aware that general permits are not less stringent than the exemption criteria and can not be used to permit damages caused by failure to install mandatory best management practices. The purpose of a general permit is to authorize selected activities thought to have minor effects; these are reviewed at 33 CFR 330 (Appendix A.)

The Corps of Engineers jurisdiction is to the ordinary high water mark or to the outer limit of associated or adjacent wetlands (33 CFR 328.1, 328.4(c)). (Ordinary high water mark is established by water fluctuations and indicated by physical characteristics such as a clear, natural line impressed on the bank, no terrestrial vegetation, or similar physical indicators (33 CFR 328.3(e)).

>>>> I Site Protection - excluding roads or trails, how well is the site protected?

It all starts here. On most sites, vegetation has supported the beneficial development of soils. The loss of any part of the vegetation protection increases the risk of accelerated erosion. If accelerated erosion gets a real start, it will be very expensive to get stopped; and impossible to restore the site productivity because of the change in the site water balance.

CWA S304(f) directs EPA to publish guidelines for pollution control from land use; these documents are "... intended to act as a state-of-the-art document useful for the development of effective programs to control nonpoint sources of pollution. Signed: Russell E. Train, Administrator" (10/73). (63)

Storm runoff volume, peak flow, and runoff distribution vary with climate, rainfall characteristics, vegetation, soils, watershed size and shape, land use, topography, and hydrologic properties of soil-cover complexes (64). Vegetative cover and litter protect the soil and provide organics that promote loose and friable soil structure. Therefore, land use practices or natural events (i.e. fire) that remove major amounts of vegetation, or accelerates the loss or oxidation of litter and humus, or creates excessive soil compaction, often drastically reduces infiltration rates and surface depression storage. Although such storms are random events and concentrated in small areas, accelerated erosion can happen quickly and set in motion long term changes in water runoff and land impairment. This is clearly not acceptable for areas where site quality protection is required by law (65 66 67).

For silviculture, soil protection is addressed in terms of both soil cover and compaction with emphasis on planning and proper design of the harvest system. As long as the 1" to 3" layer of surface organic matter remains intact, and infiltration rates remain high, there is seldom any detachment and subsequent transport of sediments. In fact there is seldom any surface runoff. However, when infiltration rates drop below rainfall or snowmelt rates, surface runoff and soil erosion hazards exist. (63).

T-Walk evaluates storm runoff using Runoff Curve Numbers (68) in combination with the 10 year 24 hour storm event. Runoff Curve Numbers (RCN) provide a systematic evaluation of ground cover, compaction, litter, and humus. The 10 year 24 hour event is a commonly used statistic for the evaluation of land use effects on storm flow and on water quality protection (37 69).

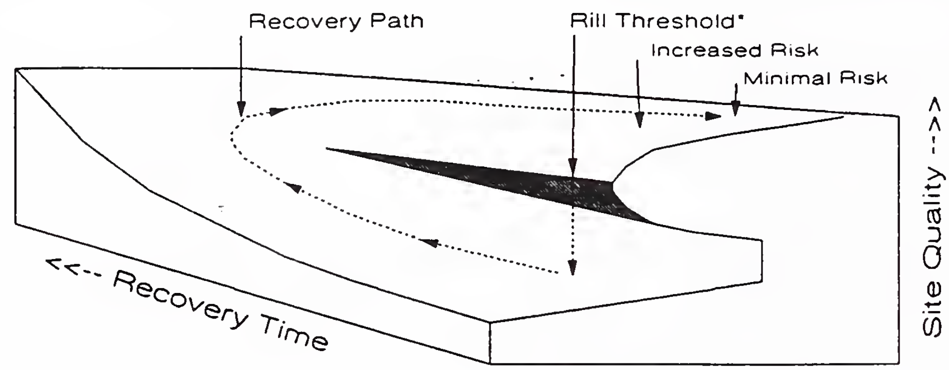
>>>> Make a contour transect across the more exposed or beat up sites and report on:

>>>> **Bare soil patterns** - show worst water concentration patterns as small & large patches that are not connected, overlap, and rills or gullies.

Runoff converted to rills and gullies moves off site so rapidly that little of it soaks the ground. There is a quantum leap in erosion and the loss of site diversity and productivity. The change breaks from one water economy to a much dryer one.

For example, visualize a 3 dimensional "S" curve and consider the upper surface as better site quality than the lower surface. Soil patterns reflect a gradient along the top of the "S" from relative safe small patches to risky 50% overlaps to the most precarious rill threshold. Any activity that forces the site quality toward the top left "edge" is harming site quality.

Site quality can often be recovered by reversing the trend and changing the management. However, if abuse continues, site quality will finally "drop" from the upper to the lower surface. Since the lower surface curves in over itself, like a backward "c", site recovery to the same upper curve position now recovers along an environmental gradient which is expensive and/or time consuming.



*Ecosystem collapse: recovery time in decades or centuries.

Site Quality Restoration

>>>> **Ground cover %** - total area % of LFH plus live ground cover.

Ground cover of litter, fermented litter, humus (LFH), and live plants together provide the primary means of erosion protection; it dissipates storm and overland flow energy. Erosional response is usually rapid following loss of adequate ground cover (70).

>>>> **LFH layer depth**, ft - long term depth of litter + fermented + humus.

The accumulation of litter, fermented material, and humus reflects the long term sum total interaction of climate, vegetation, parent material, topographic relief, aspect, animal life, and human influence. The organics so represented reflect the litter as raw material for biological decomposition, grading through the fermented layer, and finally to humus. Humus is the power house behind the site quality, site diversity, and productivity. The recovery rate is very much dependent of the LFH layer (71). T-Walk uses the LFH layer to estimate the time it takes to regain adequate site protection; this is discussed later.

>>>> II Concentration factors -
>>>> How are pollutants brought together and concentrated?

Knowledge of pollutant sources, amounts, persistence, mobility, pervasiveness, media pathways, and associated risk to health and environment is a prerequisite to gaining control (72). When runoff is allowed to concentrate, the erosive power and transport power increase exponentially. If the increase is great enough, the channel adjusts with accelerated erosion of beds and banks.

As you reread the mandatory road and trail BMP's (33 CFR 323.4(a)(6) and S208), note their relationship to reducing the effects of concentration: by minimizing the time and space that disturbed areas are subject to concentrated flow, by maximizing the sediment control through buffers or other techniques, by minimizing the risk of washing out fills or creating accelerated erosion, by preventing direct discharge into critical habitats or special aquatic sites:

- limit road & trail system to the minimum feasible number, width, and total length consistent with specific operations, topography, and climate;

- all permanent and temporary roads shall be located sufficiently far from streams or other water bodies (except for crossing) to minimize discharges;

- crossings shall be bridged, culverted, or otherwise designed to prevent the restriction of expected floods flows;

- fills shall be properly stabilized and maintained during and following construction to prevent erosion;

- all temporary fills shall be removed in their entirety and the area restored to its original elevation;

- avoid discharges into ... T&E critical habitat, specially classified waters like Wild & Scenic Rivers or Outstanding National Waters, or special aquatic sites, including wetlands and pool and riffle sequences.

- except at designated crossings, wheeled or track-laying equipment shall not be operated in protected streamcourses (10 25).

T-Walk focuses attention on the physical processes that concentrate pollutants from normal land use activities. If you focus your attention of cost effective ways to minimize connected disturbed areas in both time and space and on providing buffer and sediment control, then stream damage can be prevented.

>>>> In particular, roads, trails, and any corridor that modifies natural drainage changes timing, volume, and peak flow delivery to streams; sediment is often carried with it.

Roads are frequently cited as a major cause of stream damage (73). That soil material is exposed and surface slopes, drainage patterns, and drainage areas are changed is a foregone conclusion; however, most damage is from carelessness -- and the attitude of indifference that turns a stream into a gutter.

>>>> For **Design roads**, **Temporary & primitive roads**, **Corridors & trails**, & **Connected Disturbed Area Acres**, record slope %, distance between cross drain features, and disturbed area channel length.

Roads and trails built into hillsides act as one-sided gullies. Natural drainage and sub-surface flows are interrupted. The combination of road gradient and contributing area is a surrogate measure of stream power available for ditch and side slope erosion; poor design aggravates slope and road prism failure.

Activities that tear-up vegetation or create paths or concentrate storm flow are bad news. Remedial efforts are nearly always expensive because the site has to be protected from storm flow energy even during revegetation. Typical methods include jute matting, fiber glass roving, or similar intensive erosion control. The best solution is to not create disturbed areas that can not be drained; make reduction of Connected Disturbed Area a high priority for remedial work.

>>>> Summarize **Surface**, ...

Several studies show that road surface erosion is greatly influenced by the surface material and amount of traffic. For example, one study shows erosion rates for heavy use on a gravel road as 7 times greater than the same road with periods of temporary non-use, and 129 times greater than light use. The cumulative impact is determined in part by the rate of sedimentation and the length of that road type in the watershed (74). Typical surface and travel combinations include: asphalt, aggregate, graded (ditch, no aggregate), waterbar and outslope, temporary roads, off-road trails, or primitive roads. (Also see Watershed Water Quality Assessment, Part 2 & 3). Both factors of road surface and traffic count are somewhat under management control and can be adjusted.

>>>> Summarize ... **Road Acres**, ...

Total up the Road acres that contribute to the stream. This indicates the scope of the mandatory BMP's and the magnitude of potential risk. Information from Idaho and Montana show that an acre of exposed road prism generates 800 - 2300 cubic feet of sediment just after road construction (75). The amount normally decreases to a stable condition in about 3 years, depending on geology, climate, vegetation, and road maintenance procedures. However, stability might not ever happen; for example, the 77 year old Pikes Peak road requires 11,000(!) cubic feet of gravel per road acre PER YEAR to maintain a use for recreation and racing (76). In the meantime, stream systems are loaded up with sediments. Good erosion control efforts reduce the exposed road prism, time exposed, and the amount of stream sedimentation (73).

>>>> Summarize ... **Rill depth** (0.1' depth for the most eroded surface)....

For any given set of slope and soil conditions, the ditch will produce the maximum erosive energy possible and consequently the maximum erosion. Normal road maintenance operations that "pull the ditch", essentially re-starts maximum ditch erosion rates by removing vegetation, cutting a vee, and often undercutting the toe slope. To emphasize, while there are many good examples of ditches that are well constructed and maintained, ditch gullying is not a trivial problem and remains a major source of sediments. For example, a sediment

buffer study in the Medicine Bow Mountains, Wyoming, found that an extra 100 feet of good forest litter is needed to filter out the sand sediments generated by foot deep gullies formed in gravel and natural dirt forest roads (77 78).

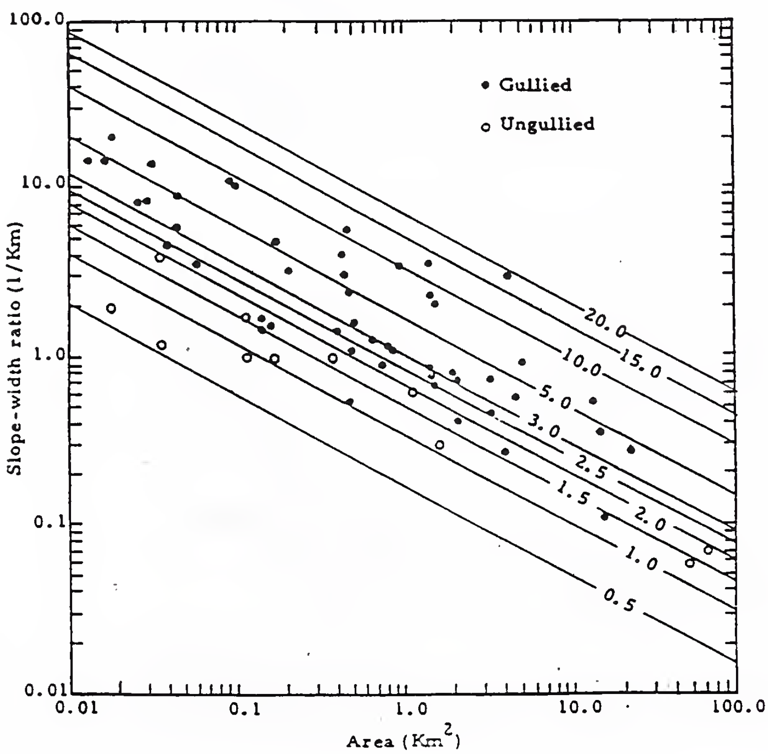
>>>> **Summarize ... & Connected Disturbed Area Acres.** Mark "at-risk" if (CDA^0.5)*Slp%/Wid' > 3.6. (Slp% & Wid' is at peak flow wetted perimeter).

Connected Disturbed Area (CDA) is a measure of high runoff areas like roads, skid trails, mines, burned areas, or highly compacted soils that drain directly into the stream system. The CDA method, based on SCS urban hydrologic analysis, is used to determine the effects of land use on accelerated peak flows and increased volumes of storm water (28).

CDA is a good link among land use, cumulative effects, and antidegradation issues. Because of the strong correlation between CDA, storm runoff, soil erosion, and sedimentation, any increase in CDA will likely result in stream health damage -- and therefore makes a good first approximation of Aquatic Ecosystem Cumulative Effects (40 CFR 230.11(g)) (29).

The objective and heart of many BMP's and mitigation measures is to reduce the CDA and revegetate sites that are exposed. Early operations that "disconnect" CDA from the stream are some of the most cost effective and beneficial measures that can be applied.

With regard to drainages that may develop eroded characteristics if diverted, blocked, or trailed, there is no one single comprehensive model. However, if CDA is expected to be the main source for peak flows, then one method, based on geomorphic concepts, is particularly valuable for assessing accelerated erosion risk. The method (based on "Stream Power" relationships among slope, width of flood flows, and drainage area as a surrogate for flow), explores the ability of water to create gullies in local geology, topography, and climate (79).



Geomorphic threshold or Stream Power Model. Lines of relative Stream Power. Note geomorphic zone between Relative Stream Powers of 1.0 and 2.0. (Harvey, etal 1985. Fig 4-16).

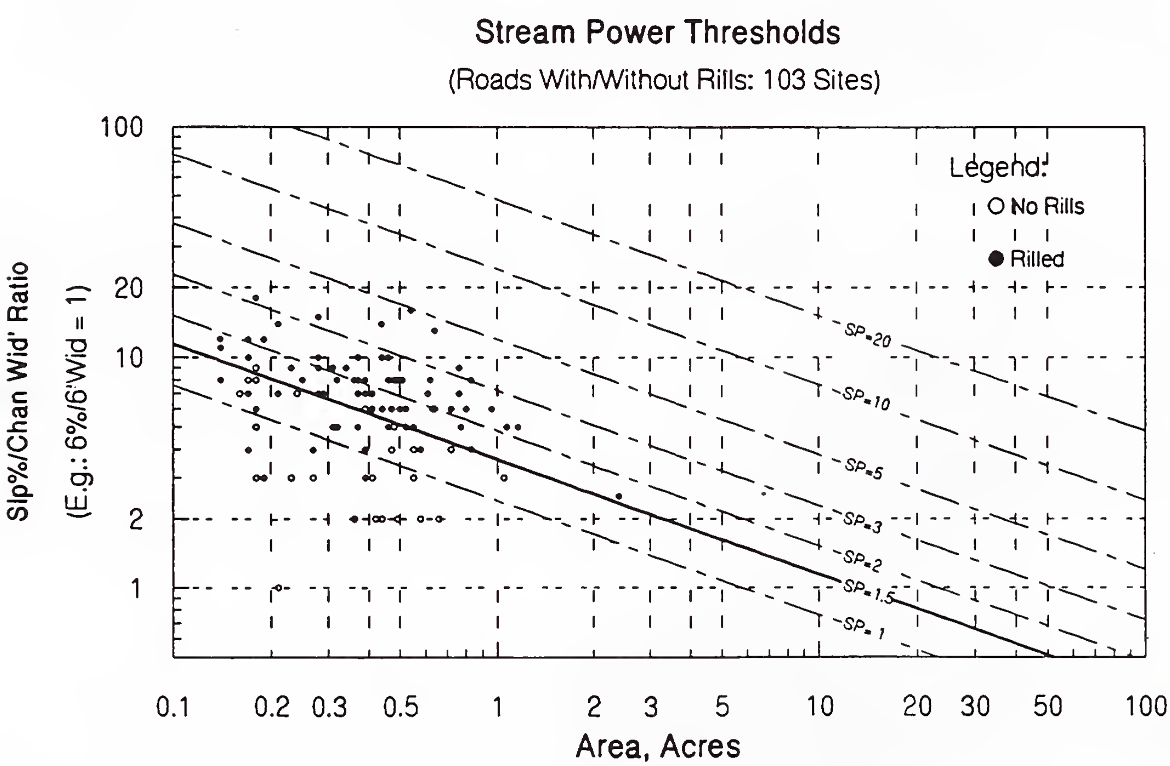
The assumption made by T-Walk is that risk of gully erosion can be assessed by comparing measured values against the critical 1.5 Stream Power value. Field determined values that are the same or less would represent little risk, while those that are greater would reflect increased risk. The SP = 1.5 equation, modified for T-Walk, has the following form:

SLOPE%/WIDTH' = 3.6 / (ACRES ^ 0.5) where:
Slope%/Width' is a ratio that combines
Slope% = clinometer read as %, i.e. 6% is 6.
Width' = wetted perimeter at peak flow, feet.
Acres = drainage area (high runoff or CDA), acres.

For a given drainage area, the Slp%/Wid' ratio sets a benchmark for a relatively trouble free condition. For example, a 10 acre drainage area has a threshold Slp%/Wid' ratio of 1.1; meaning that a 6% channel with a flow width of 6' would be stable, as would a 10% channel with a flow width of 10'. But a 10% channel with a flow width of 2' (like a rut) would not be stable. Or you could determine the Slp%/Wid' ratio under field operations and calculate the drainage area that can be safely accommodated; i.e 10% channel, 2' ruts is "safe" at 1/2 acre.

Or you could solve (CDA^0.5)*(Slope%/Width') from field data or expected project conditions and see if it is over 3.6. If so, then consider the field condition "at-risk" from the standpoint of gully erosion.

The data on the graph show rill conditions on 103 road sections located in the Medicine Bow Mountains, Wyoming, and in the Black Hills, South Dakota (80). The data points suggest the sensitivity of exposed sites to high intensity storms.



>>>> III Dispersion factors -

>>>> Where do pollutants and sediments end up? For example, stream impacts from excess sand remain until they are flushed into deep water or dredged out. Objective: keep pollutants out of water to start with.

The flexibility of management combined with diverse natural landscape features provide adequate means for keeping sediments and other land based pollutants out of the stream. The intent of most best management practices is to provide for dissipation of concentrated energy and to use the soils' own natural processes to recycle nutrients and biodegrade other materials.

>>>> **Permanent vegetative buffer** - least-cost long term sediment control:

Vegetation has the ability to incorporate sediment into the soil development and anchor it with the root system. Vegetated buffers can - or at least should - be designed and managed to accommodate the long term pollutant yields. There are good design criteria for sediments, nutrients, heavy metals, and biocides (81). Please take the long term view and design pollutant and sediment loads to be fully accounted for by the buffer; anything less puts a burden on maintenance budgets or, horrors of horrors, on litigation and restoration.

>>>> **LFH depth**, ft - buffer long term litter + fermented + humus depth.

How fast the site will incorporate delivered sediments can be inferred from the litter, fermented, and humus depth as discussed under site protection. It makes a good filter for overland flow if it is sufficiently heavy and anchored down.

>>>> **Slope %** - average slope of area used as buffer.

The steeper the slope, the greater the risk that rill and gully erosion will be started. The buffer slope needs to be without rills or gullies and internally stable at expected moisture levels. It is important not to cause mass failure; so if it looks too close to call, invest in a slope stability analysis.

>>>> **Ground cover %** - total area % of LFH plus live ground cover.

Wonderful stuff, vegetation. It is the heart of the resistance forces that keep the buffer from becoming eroded. Rooted vegetation anchors site material, traps sands, spreads out surface flow, and reduces flow velocity. Look for signs of vegetation stress or old rill patterns; buffer equations must be adjusted if the vegetation is dying or the surface is already cut up into small channels.

>>>> **Expedient traps** - temporary measures; but they must last long enough to prevent overwhelming the natural buffer capacity and to meet revegetation standards on exposed sites.

Find a cheap way to keep construction debris and sediments out of the stream without destroying the existing buffer. Locate the trap so it will be easy to stabilize and maintain. You might check the EPA handbooks on preparing storm

water pollution plans for construction activities (82). Also, use materials that will biodegrade and look part of the natural setting; this will save you an extra trip to clean up the junk.

>>>> **Time left, yr** - estimate current fill rate & remaining life.

The best traps are empty and there is value in keeping them ready for the big hits. As the planned erosion control is accomplished, there will be less risk. Less risk is another reason to keep the erosion control efforts on schedule.

>>>> **Kind of trap** - common temporary sediment control treatments
>>>> Ebsn Expedient sediment/debris basin.
>>>> Ecut Expedient in-channel trench or trough cut; no dam.
>>>> Efil Expedient filter/sorbent material fence.
>>>> Efur Expedient log & furrow sediment control.
>>>> Epit Expedient small sediment catch 'pit'.
>>>> Erow Expedient slash/brush wind row.

Common sediment traps are simple to build with the manpower and equipment normally expected on site. Try to use maintenance-free traps. For example, the normal installation of sidehill culverts can include a "pit" or hole at the outlet. The culvert installation is the same; there is just a hole down slope to catch the sediments. By the time the pit fills up, the erosion control efforts are supposed to be in place, and no further pit maintenance is needed.

>>>> **Stream receptor** - Sediment yields are tough to estimate. Start at the worst sediment source, track the eroded sand material through the buffer and temporary traps, then estimate what % made it to the stream. Estimate **Sediment yield %** as that part deposited into the drainage feature. Since the receiving stream condition is also important, record what it is: perennial or intermittent, bog or wetland, overflow, ditch, or a swale.

Material that enters the stream from land use activities creates liability. The actual amount of **sediment yield** to the stream is the real test of standards and guidelines: Did the <u>job</u> get done or just talked about?

T-Walk is most directly concerned with perennial streams as deposition sites. But pollutants are pretty tough to just "put" somewhere, so consider what pollutants are going to move with storm runoff. Deposition in intermittent or dry channels, ditches, or overflows is just not adequate; when flow starts, the loose sediments are moved along. Dry vegetated swales will hold sediments if there is no distinct channel (77); otherwise there is no storage opportunity.

>>>> If roads are a major source, **Sediment yield %** is the % of culverts & drains that lack an adequate buffer or flows direct into the stream network.

Sand travels. New sand deposits are fresh and bright, and with some experience, should be obvious on vegetated buffers and on the stream bottom. Since each geology and vegetation has its own characteristics, take the time to walk down a

typical road and get a feel for normal sediment and buffer conditions. At each cross drain, look for the sand flow distance and whether there is a stream hit. The ratio of stream hits to the total number of cross drains sampled gives an estimate of sediment yield percentage. For example, if 1 out of 6 culverts drain into channels and the rest onto buffers, the sediment yield is, at least, 17%.

With this field experience, you can then estimate sediment yield percentages as a function of cross drains that are not adequately buffered and the extent to which the existing vegetation is likely to trap sediments. To validate the **Vbfr** buffer equation for the test area, measure cross drain spacing, grade, rills, and buffer conditions, then compare what you see with the **Vbfr** equation.

You must also add material from mass failures. These may be so located that buffers designed for cross drain discharge are adequate. Or the mass failure is so prevalent that buffers are ineffective and sediment yields are nearly 100%. However, keeping roads off unstable areas saves a bundle of grief.

>>>> If the **Vbfr** equation calculates a buffer length greater than the field condition, the buffer is too short. The **Vbfr** equation is based on data from paved, gravel, and dirt roads; it is applicable to most watershed development activities.

Vegetation as erosion protection and as a sediment filter is the most cost effective way to eliminate stream damage. Design buffers for long term conditions and use temporary measures for short term impacts.

The Vegetative buffer equation, **Vbfr**, is oriented to engineering and physical criteria on rock types that weather out sands. Granite, gneiss, gabbro, schist, limestone, sandstone, alluvium, and glacial drift are represented in the original 1974 data set and subsequent verification (77 78 83 84).

The **Vbfr** equation has a perspective for control of sediment from quality land management. The original data set did not include large road mass failures, large and frequent additions of extra sand or gravel, discharge onto heavily rilled surfaces, vegetation conditions with less than 30% ground cover, slopes over 40%, or on rock types that do not weather out sands. However, for some circumstances, like fires, you may not have any other choice than the equation; if so, apply with generosity and remember the point is to keep sand materials out of the stream.

>>>> **Vbfr= [10 + 10xRms + 100xGdp]/[Vcvr]** where:
>>>> Vbfr = vegetated buffer needed to trap road & ditch erosion, ft.
>>>> Rms = (Road cross drain distance/1000) times (Road slope%)
>>>> Gdp = Ditch cutting or gully depth in the ditch bottom; 0.1 ft.
>>>> Vcvr = Buffer Type (SEDFLOW) or = (plant + crs wood & herb litter, dec%).

>>>>

	Buffer Type & Condition		Vcvr	Expect'd & Range
S	Swale	undisturbed; no rills	0.4	0.3 - 0.5
E	Eroded	old rills common	0.2	0.1 - 0.3
D	Drops	holes, depressions	1.0	1.0
F	Fans	sidehill & ridge, no rills	(plant + crs wood & herb, dec%)	
L	LWD	windrows, slash, natrl falls	1.0	1.0
O	Open	trails, paths; not connected	0.4	0.3 - 0.7
W	Wander	cobbles, hummocks; no rills	1.0	1.0

Providing an adequate buffer to protect streams from roads and trails is a mandatory condition of the S404 exemption. Over the last several years, buffer equations have been selected and sometimes mandated for use. But, none are in general use. Sometimes there is a lack of trust in the results, or a lack of time to collect the data, or they don't apply to the full spectrum of normal road engineering (85 86 87 88 89).

However, these studies still provide the foundation used in the construction of **Vbfr**. In particular, Packer and Christensen's orientation to the physics of road gradient and cross drain engineering, along with the character of geologic erosion and vegetation roughness was retained in the Rms, Gdp, and Vcvr factors (84 85). Buffer slope was not retained as a factor; vegetation in terms of its roughness (86 87) and ground cover density (88) were found to be more usable in the context of land management and stream health protection. Buffer shape is used to modify Vcvr if shape becomes a controlling feature (83). The Sediment Delivery Index (developed by the Forest Service) used linear scales for buffer shape, roughness, and factors like hydrophobic soils, minerology, microrelief, and soil aggregates (84).

Use the **Vbfr** equation to make simple field evaluations of engineering choices about road grades, water drain location, and ditch stability. After construction, road grades are not likely to be changed, but drainage distance can be shortened or ditches stabilized if necessary. The factors -- 10, 10, and 100 -- make it easy to remember and a M+ calculator will do the figures. Rms is a measure of erosive power acting on the road itself; Gdp is a measure of the resistance of road material to the erosive force. Both are translated into the vegetative buffer as distance required to filter sand materials out.

The Vcvr divisor is a measure of existing (or expected) vegetative cover, and may be a measure of more general factors that override specific vegetative control. For example, a given sediment flow on a well-vegetated buffer with an old embedded rill pattern is likely to be 5 to 10 times longer than a similar, but unrilled, buffer. Buffer slope, combined with geology, soil infiltration, and existing land use, is a major factor in predicting both slope failure and/or gully and rill erosion on the buffer. Any such channelization greatly decreases -- or if it connects with the stream, eliminates -- the buffers effectiveness.

Current experience suggests that there are seven basic buffer types that can be used to characterize general sediment flow patterns; these are organized into the acrostic "**SEDFLOW**" to help you remember them:

S = Swales: as undisturbed vegetation & no concentrated flow;
E = Eroded: healed rills or small gullies (disconnected from stream);
D = Drops: holes or depressions);
F = Fans: smooth sideslopes or ridges that allow sediment to fan out;
L = LWD: large woody debris (4">) oriented to create barriers;
O = Open: flow along paths or trails (disconnected from stream); and
W = Wandering: spreading flow thru rocky material (2.5">) or hummocks.

Small scale roughness features that keep flows spread out and trap sediment tend to be more affected by management activity than general buffer shape. Small features are indexed using live plant cover, woody debris, and coarse herbaceous litter. Small or fine litter is not counted unless it is tied down and can not float away under storm runoff conditions.

>>>> Thalweg Depth (by tally)

>>>> This is the heart of **T-Walk**. The purpose is to characterize the thalweg depth and evaluate substrate conditions that influence fish food production.

The T-Walk takes its theme from a walk in the stream. The physical and biological part of T-Walk means getting your feet wet and becoming acquainted with the character of the channel from the bottom up; it is not a desk exercise. Drowning, of course, is counter productive; so be careful.

One major impact to diversity and production is the loss of pool depth and the loss of macroinvertebrate production. Changes in either one or both parameters are suitable measures for a variety of land use impacts including logging, road construction, canals, mining, and grazing (90 91 92 93 94 95 96 97).

>>>> Location is important. **T-Walk** must be done close enough to address stream impact, but not so close that sacrifice (wipe-out) areas are included. For example, leave 200' below construction sites before starting a T-Walk reach.

Contrary to popular belief, the Clean Water Act does not have a hidden agenda to prevent land management and the orderly development of natural resources. For practically any purpose, there will be some impact -- some area sacrificed to meet an operational need of management -- and the Act supports this reasonable approach (98). The key is to keep the impact confined to a reasonable area. Two guidelines are used: 1) stay outside direct construction zones such as road crossings; and 2) stay within 660 feet (above & below dimensions for 40 acres).

The point is to check on spill-over effects that are not covered by permit. The best location is generally just outside of the impact area with features that favor advance warning of impending damage and on selected weaklinks within the stream system (99). Typical weaklinks include short radius meanders, raw banks, steep bank slopes, highly erosive soils, lack of vegetative protection, mass failures, or combinations of several factors.

One special situation is the problem of sediment spills. When very large volumes of sediment are readily available for transport, such as from a road washout, then the T-Depth survey should start just below the road (with no 200' comfort zone). The difference between the "before" and the "after" failure can be inferred from a T-Depth taken twice at the same point; that is, take a reading on top of the deposits and a second reading with the probe pushed through the deposits to the firm (original) bottom (49).

\>>>> Work along the reach at equally spaced distances. Surveys with 30, 50, or 100 points are common. Select the number of points that will pick up the variety in pool depths. For shallow streams (<2') with regular features, 30 points (22'±) provide minimum statistical control. For deeper streams or those with pool-riffle or step-pool sequences, 50 points (13'±) are needed to provide minimum statistical control (2/3 chance) and 100 points (7'±) provide substantially better statistical control (9/10 chance).

At each point, check substrate size, sand infill, and vegetation within the low flow channel; then measure the deepest thalweg depth (1/10'). Looking carefully at the stream bottom helps identify excess sand moving into the system during the early stages of deposition. Most obvious will be small sand waves or dunes building behind larger rocks, or more than a 10% covering of larger rock surfaces. Current experience suggests that you ought to do at least 50, or better still, 100 points on most mountain streams (42).

When streams are very small and it seems pointless (pun) to go the full 1/8 mile, then use a stream reach length of at least 210' (30 points x 7' spacing), of 2 full meanders, or 20 times the channel width, whichever is greater. The 7' spacing is usually satisfactory (41 42 60).

Sometimes stream reaches of more than 1/8 mile are needed to provide information about channel features or to cover 2 full meanders. Feel free to make the longer survey, but make sure you record the length and the spacing between the points. There are several options; for example, if the reach is 1000', then 50 points at 20' or 100 points at 10' or 142 points at 7' are all choices.

\>>>> **Thalweg Depths** - low water surface; tally depth by category.
>>>> **Qbf to water surface 0.1'** - provides year to year stage reference. If Qbf is not used, note precisely what was & location.

Thalweg depths can be summarized to show changes in pool and riffle character. Bankfull stage is an important field indicator that remains relatively constant; the measure from bankfull down to current water level provides a reference for comparing the plots of depths made in the same place at different flow levels.

When bankfull marks are not easily identified, then the stage reference must be to something else such as a large rock or concrete bridge abutment. Be sure that what you use is described so the next survey party can find it. The measure is necessary in order to capture year-to-year survey variation so changes can be properly assigned to sedimentation effects. The measurement is not particularly critical except in very shallow streams. For example, for many systems with 2' deep pools, a large error of 0.2' in making the measurement from bankfull to the water surface is still only 10%. Current experience suggests that sedimentation can often eliminate 1/2 or 2/3rds of typical pool depths.

>>>> **Thalweg velocity '/s** - if hiQ use 0.8x float vel or 8*sqrt(vel head).

Variable stream flow and corresponding stream width, depth, and velocity profiles influence sediment transport, channel shape, bar deposition, bank cutting, and the distribution of stream bed materials. All of which have a major influence on the structure of plant and animal aquatic communities.

If you use floats, set them to travel the thalweg. If the flow is low, use the veolcity as measured; if the flow is more than 1/4 bankfull, take an average of the surface velocities and multiply by 0.8 (rough bed and 0.9 for smooth bed) to get a thalweg average (100). The velocity head rod is only recommended for solid and smooth stream beds with velocities near 1 ft/sec or more (101).

>>>> **Max & Min depth 0.1 ft** - record maximum & minimum of all points.

The deep spots reflect the range in diversity and provides the necessary margin of survival during long dry seasons and is specifically considered under the <u>Diversity Screen</u>. The minimum depth can also serve as a reference for comparing the plots of depths made in the same place at different flow levels. A simple cuff record during the survey helps you remember these values.

>>>> **Pool, Veg, Shore, & Jam** - dot tally for use in the Diversity Screen.

Current experience suggests that you will save time if you dot tally the pool, vegetation, shore, and number of jams during the T-Depth and Tarzwell Substrate Ratio part of the survey. The items are discussed under the Diversity Screen.

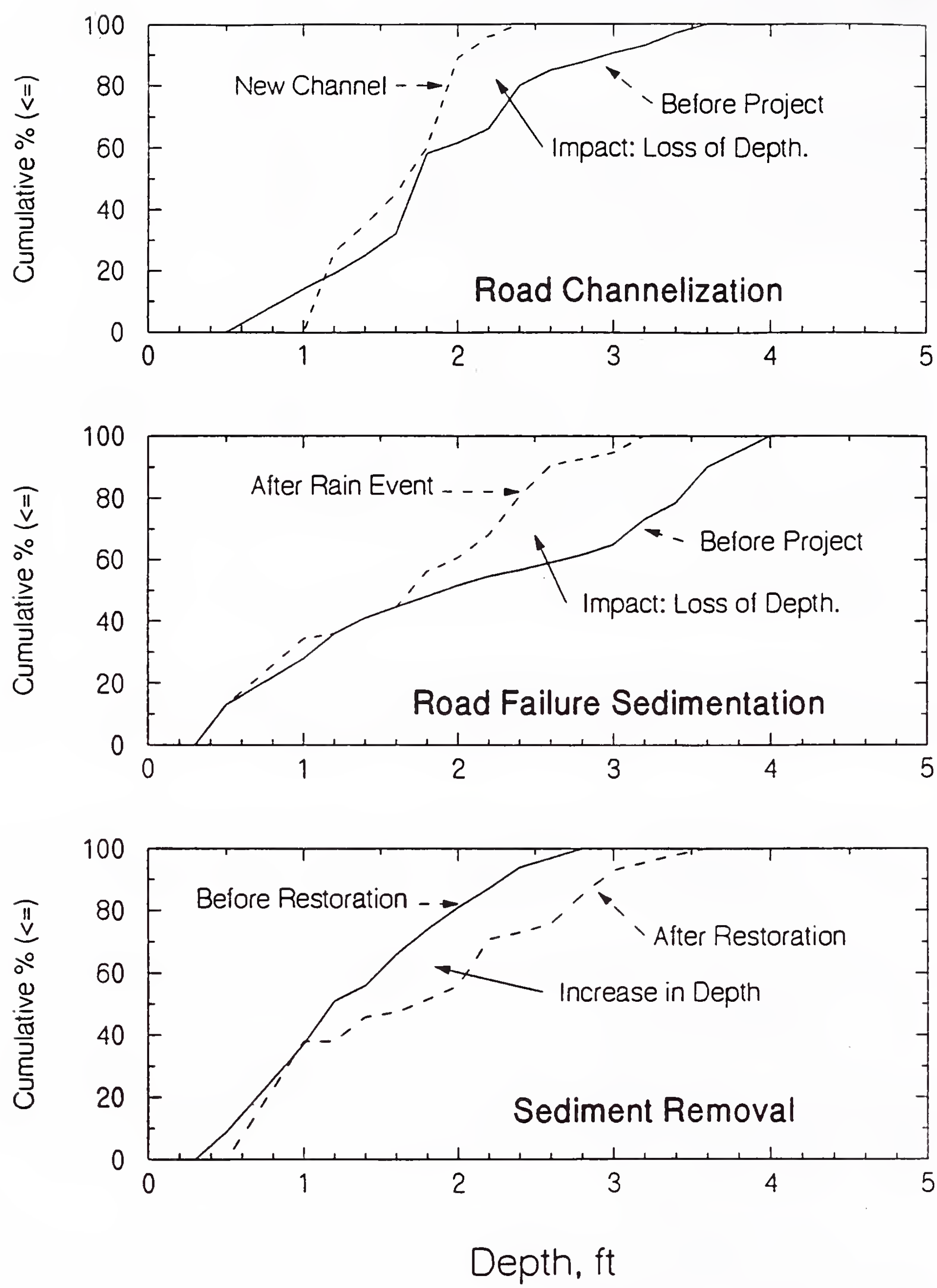
>>>> **Depth Categories** - at each point measure the thalweg (deepest) and tally the appropriate depth category. At end, convert tally into <=% category exceedence values and plot using max & mins as graph limits.

Diversity and productivity are served by a variety of depths. The thalweg depth profile includes the range in riffles, pools, glides, and runs; but does not try to define each individual feature.

After the depths have been tabulated, add up the hits equal to or less than the upper category range; then convert the summation to cumulative %. Then, using 0.1" arithmetic scale paper, plot cumulative % on the vertical axis against the depth category, upper limit, on the horizontal axis.

If the reference reach and project reach data are plotted together on the same Cumulative % vs Depths graphs, then impacts or shifts can be easily seen. For example, thalweg depth profiles might show loss of depth by comparing depths measured before and after a road channel change or a road failure, or the recovery of pool depths from sediment removal using a suction dredge.

Thalweg Depth Profiles



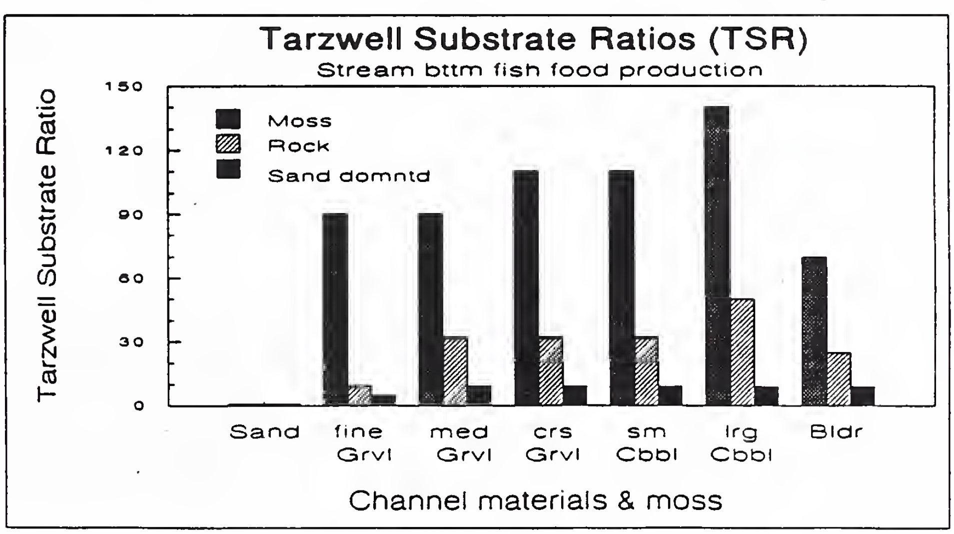
>>>> Tarzwell Substrate Ratio (by tally)

>>>> Sedimentation of coarse substrates by sand produces significant detrimental effects on salmonid resources by affecting spawning areas and by reducing primary and secondary production. **Tarzwell Substrate Ratio** is a dimensionless measure of macroinvertebrates produced on different substrates indexed to sand as the least productive. The tally uses 3 groups: sand dominated substrates, rock dominated substrates without excess sand, and substrates influenced by vegetation or organic matter. Excess sand shows as waves behind larger rock, as dunes or ripples, as embedded gravel, or as buried plants. Sand infill begins when >10% of larger rock surface or perimeter is obscured.

Biological integrity includes production. The most generic concept is ecological carrying capacity; in the context of T-Walk the best choice appears to be the Tarzwell Substrate Ratio as a measure of macroinvertebrate habitat (102 103).

The T-Walk takes this opportunity to recognize Dr. Tarzwell's work and it's application to the problem of evaluating sediment impacts on macroinvertebrate production in coarse substrates. During the 1930's, the Michigan Emergency Conservation Workers agency did extensive in-stream structure work on 6 rivers. Over a 5 year period, Dr. Tarzwell analyzed 447, 2' by 2', bottom samples taken from substrates that represented typical stream conditions before as well as after restoration efforts. Part of his results included summaries of fish food production ratios for 25 different substrates including those influenced by vegetation. The ratios are particularly valuable because they are based upon a substantial data set for several common types of coarse bedded substrates and demonstrate what can be achieved with simple restoration techniques.

While his work was done primarily in Michigan trout streams, the use of substrate ratios allow the extrapolation to other areas. For example, Tarzwell's work for the U. S. Forest Service in New Mexico concluded that while the actual production was different, the substrate ratios were similar. In the 1970's and 1980's, EPA confirmed that Tarzwell's substrate ratios had enough geographic application to warrant their use in national water quality field training manuals (104). The use was considered appropriate for evaluation or until replaced by locally generated production information.



Since the T-Walk use of Tarzwell Substrate Ratios is based on observational data; the question of repeatability and consistency has to be resolved before there is extensive use. Preliminary field results are encouraging, and when combined with EPA's early use, suggests that field use of the Tarzwell Substrate Ratio can be used in T-Walk. However, Platts shows that consistency in cobble embeddedness data varies enough from individuals and year to year (105) to make analysis of effects difficult. As of 1994, the expected variation for routine field use of Tarzwell Substrate Ratios has not been fully explored (106).

>>>> **Tarzwell Substrate Ratio** - Near the depth tally spot, visually match the substrate to the TSR categories. If you can't see, try a snooper. Individual rocks sometimes indicates embedded condition by color change or animals just only along the fringe. When tally is complete, convert dot tally into % for each category, multiply category TSR by its %, and total. The total is an average Tarzwell Substrate Ratio for the reach.

By identifying a shift toward sand dominated substrates, the T-Walk rationale infers that there is a substantial decrease in production. For example, adding excess sand to a normal cobble substrate with a Tarzwell Substrate Ratio of 32 will reduce the ratio to 12; this is a drop of about 2/3rds. Choose reference conditions with care; many natural systems on nutrient poor rock types or at high elevations will tend to have little or no instream vegetation and some erodible rock types produce sand dominated substrates as a natural condition.

The reach composite Tarzwell Substrate Ratio is an average value for the whole reach. The last step is to divide this TSR by the reference TSR to obtain a ratio for the reach relative to its potential.

The T-Walk interprets any production ratio greater than 0.9 as fully meeting the pristine or reference standard; this is called "Robust".

Production ratios of 0.7 to 0.9 are considered "Adequate" if - and only if - the reach is part of a sacrifice area taken for some specific management facility such as a road crossing or a range water development or is covered by a CWA S 404 or similar permit; otherwise, it is called "Diminished". It is critical to understand that general logging, grazing, recreation, or road construction needs to meet "Robust" Stream Health production ratios and to create "no impairment" within the meaning of the S 404 exemption (107). The FS does not have authority to degrade the productivity of any resource, let alone water quality.

Ratios 0.5 to 0.7 are considered "Impaired" regardless of its association with management facilities. Ratios 0.3 to 0.5 are termed "Precarious". Ratios less than 0.3 are termed "Catastrophic".

Every evaluation system yet created can be fiddled to make the right answers appear, and T-Walk is no exception. Areas showing degraded conditions may be under pressure to re-define the reference or move all the sample points away from the impact. Don't do it. The production side of stream health is one of the main antidegradation guns; sooner or later the axe will fall and some heavy duty restoration will be forced upon recalcitrant agencies (or culpable individuals). Anticipate the need for follow-up monitoring and stay on top of the changes.

>>>> <u>Channel Materials</u> - mark d50 & d84 of surface materials (i.e. Pebble Count); note bimodal distributions. Be specific but without forcing the data. Remove the top layer to check subsurface materials; note any unusual layers or size combinations. Look for d84 for the bankland rock composition; slope stability depends on the structural interlock provided by larger sizes.

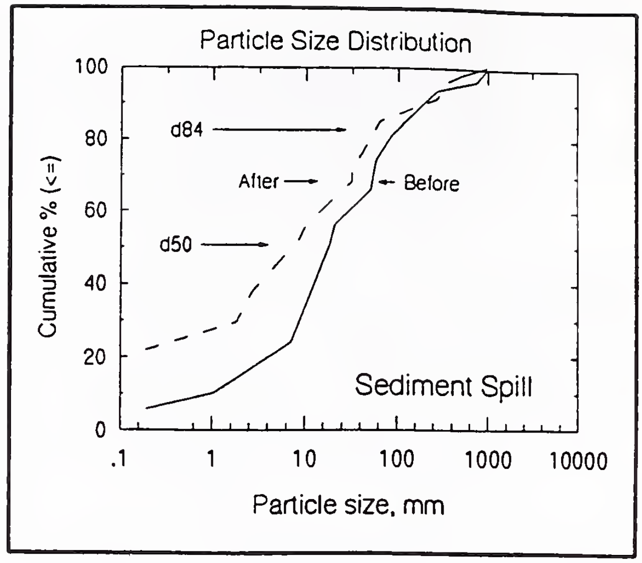
Differences in origins and particle size distributions of stream bed and bank materials influence the relative rates of stream processes and are reflected in the stream's hydraulic geometry. The analyses of these factors -- namely slope, width/depth ratios, meander patterns, pool-riffle sequence, and bed longitudinal profiles -- tend to be part of fisheries and hydrologic studies. They are key items in understanding watershed response and stream health (60 95 108 109 110).

The classification, measurement, and analysis of particle size distributions used by T-Walk is based on a method of sampling coarse bed material developed by Wolman (111) and modified by Bevenger (112). The Wolman Pebble Count is a systematic sample of 100 rocks taken in shallow (<2') streams and tabulated by standard categories (table). The sampling pattern depends on the purpose; but, a typical survey produces a composite particle size distribution by sampling equal numbers of cross sections located through pools and riffles.

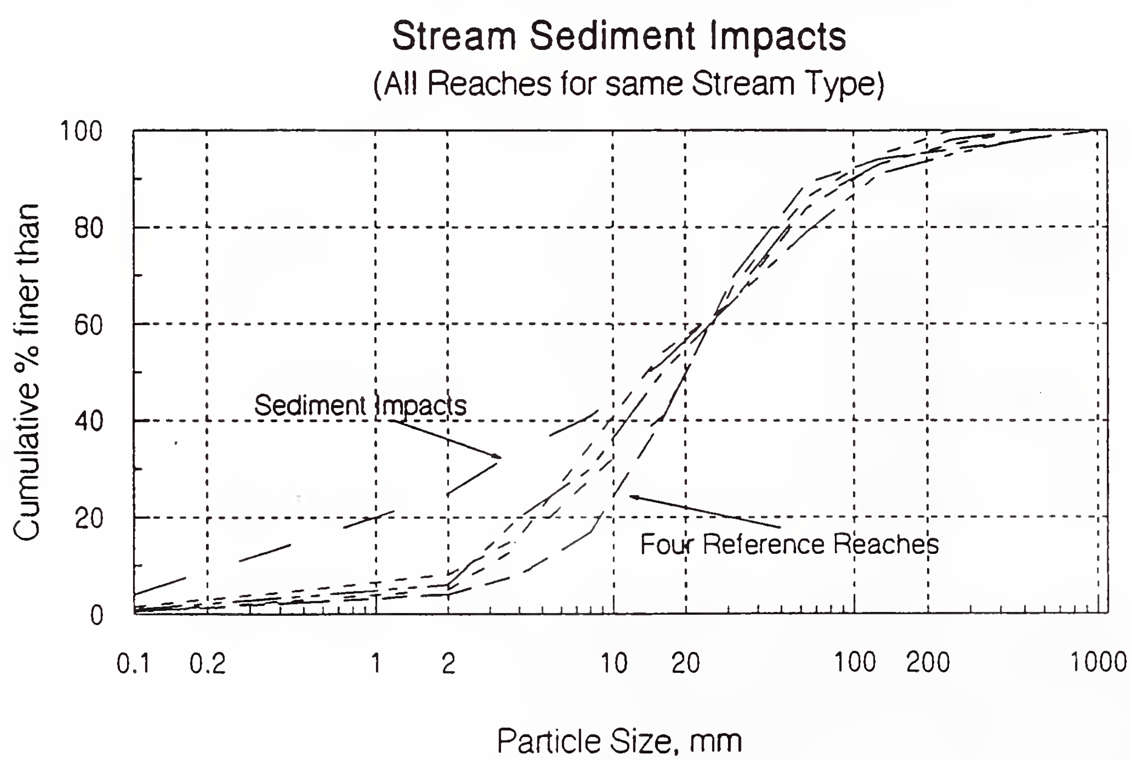
The Bevenger modification uses a zigzag pattern throughout the reach, rather than cross sections, and thereby eliminates the bias introduced by selecting cross sections. If the reach is 700' long and sampled at 7' increments (typical for T-Walk), then the sample size of 150 provides an efficient statistical design for comparing stream reaches to reference conditions. Current experience suggests that differences in fine sediment loading of 10 - 15% can be picked up with n= 150 or 12 - 18% with n= 100. (113).

Channel Material Size Classes (Am. Geophysical Union; Lane, 1947)

Class Name		Millimeters	Inches
Bedrock		4,096-more	160-more
Boulders,	very large	2,048-4,096	80- 160
"	large	1,024-2,048	40- 80
"	medium	512-1,024	20- 40
"	small	256- 512	10- 20
Cobbles,	Large	128- 256	5- 10
"	Small	64- 128	2.5- 5
Gravel,	V. coarse	32- 64	1.3- 2.5
"	coarse	16- 32	0.6- 1.3
"	medium	8- 16	0.3- 0.6
"	fine	4- 8	0.16-0.3
"	v. fine	2- 4	0.08-0.16
Sand		0.062- 2	
Fines	silt & clay	less-0.062	



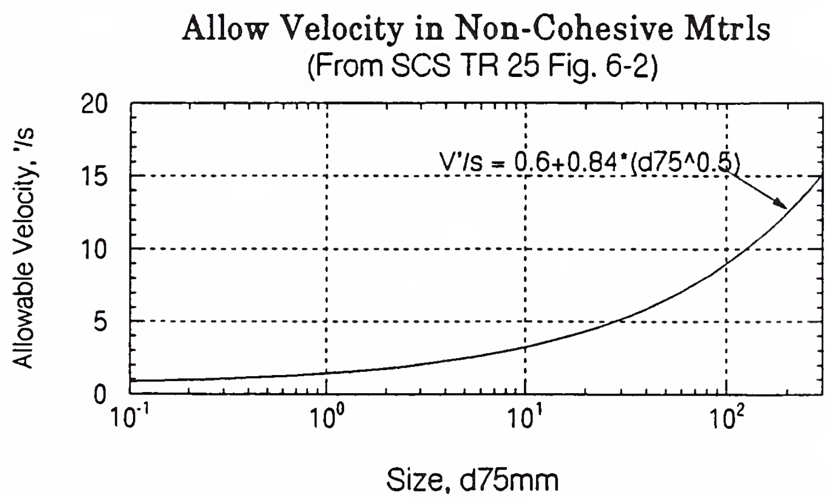
Particle Size Distribution
100
80
60
40
20
0
Cumulative % (<=)
d84
After
Before
d50
Sediment Spill
.1
1
10
100
1000
10000
Particle size, mm



Stream Sediment Impacts
(All Reaches for same Stream Type)
100
80
60
40
20
0
Cumulative % finer than
Sediment Impacts
Four Reference Reaches
0.1
0.2
1
2
10
20
100
200
1000
Particle Size, mm

>>>> Find high flow stage (Qbf); note d84 of weakest layer or plane between different sedimentary beds. Bank strength is an integrated feature: note cohesive matrix (yes/no); non-cohesive or slip lens; rooting at Qbf (if yes, mark grass, shrub, or trees); pipe or side fracture; and large woody debris (lwd = 4" >).

Channel stability is attained when the bed and bank material at the boundary effectively resists the erosive energy of all stages of flow and the channel remains essentially unchanged. For T-Walk, the stability relationship is best expressed as allowable velocity for particular channel conditions (114 115).



>>>> **Mark** the geologic rock types that dominate in the stream feature; be aware of unusual combinations like shale overlain by sandstone cobble. **Form choices:** basalt, granite, limestone, marine shales (high salt), mixtures like outwash, rhyolite, schist, sandstone, shales, volcanics.

Weathering of particular rock types also produces characteristic chemical mixtures that dictate long term stream productivity and response to chemical impact. In particular, low levels of hardness and alkalinity are of concern: first, because the low buffering capacity can be overwhelmed by spates of acid rain or snow; and second, cadmium, copper, lead, nickel, silver, and zinc ions are more toxic at lower levels of hardness (116).

>>>> **Channel Physics** - stream health is sensitive to stream energy and channel geometry changes. Obtain **Watershed area & mean elevation** from the map.

Watershed area and mean elevation are major players in stream forming processes; they are treated with respect by T-Walk and incorporated in the definitions of stream health. For example, biological richness tends to increase with increasing stream size and decrease with increasing cold and/or dry climates. Stream health handles the difference by using the reference reach as the standard and does not impose a downstream standard.

The statistical regressions of watershed area and mean elevation to stream discharge, width, depth, and cross-sectional area are often well correlated. For Stream Health, this means that reference sites have to share a fairly narrow area and elevation range in order to provide a true test.

>>>> Use a mounted 5x hand level & survey rod (or cord & line) to measure **Channel Slope** (water surface); do it carefully.

Heard the one about the 'hydrologic cycle'? Thats the cycle that uses solar power to evaporate surface water, make clouds, falls as rain or snow, runs-off, then re-evaporates. In the process, the potential energy created by the lift is converted to kinetic energy by the fall. By the time the water has returned to the sea, all of the kinetic energy has been used up by frictional heat loss and by transporting material downhill. Stream power, at a site, is a measure of how fast that energy is converted.

Channel slope drives stream power because of its gravity component. The two extremes are flat (kinetic energy = 0) and vertical (kinetic energy = max). In terms of formula, stream power in ft-lbs/sec = 62.4 x cfs x slope '/'. The equations used to model the gravity component are very sensitive; for example, to go from 0.5 to 1.5% slope triples stream power.

>>>> Note if this is a **Step-Pool** system.

Some streams develop a **step-pool** structure. The step is a local gradient control imposed by features such as rock ledges, boulders, or large woody debris. Since much of the potential energy is dissipated in plunge pools or cascades, stream power is controlled by local gradient rather than average stream gradient.

Depending on the geology and past watershed land use, **Step-pool** systems might store a large amount of in-channel sediment. The practice of snagging or removing large woody debris from channels often causes severe erosion and sedimentation problems and needs to be reviewed for long term effects (117).

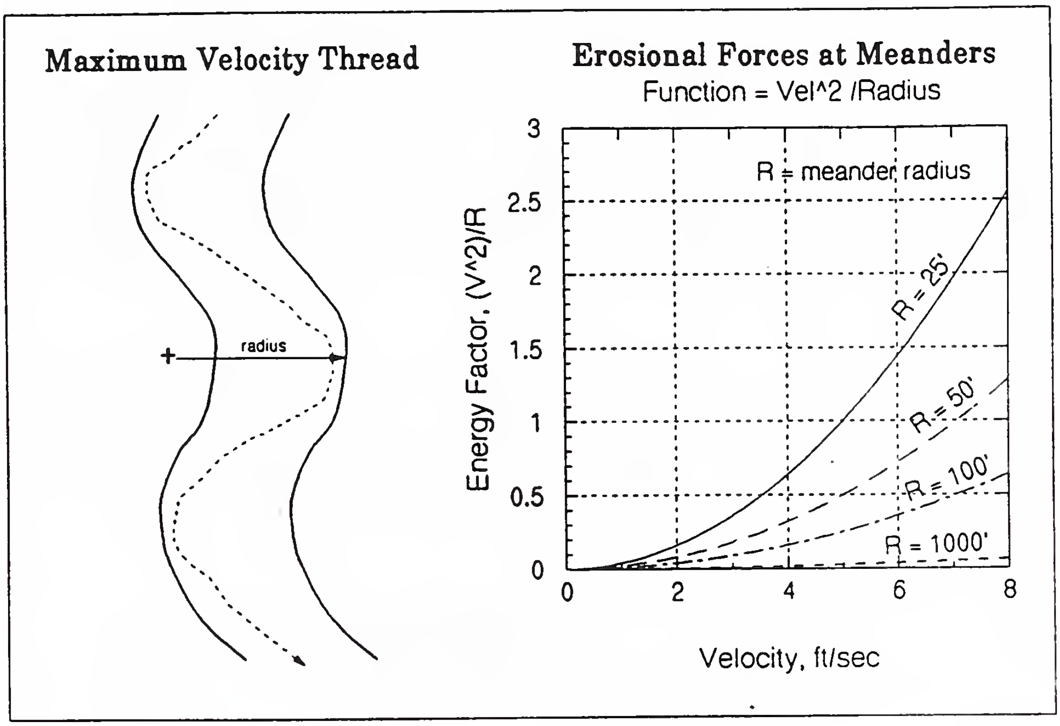
You may encounter **step-pool** systems with stability problems. It was common to use streams for early-day log or tie drives. The operation was to fill a splash dam, drop the gate to create a flood, and flush the logs down stream. Any feature that obstructed the drive would be removed, dynamited, or channeled around. Many such stream systems have not yet recovered and are still unstable.

>>>> Sinuosity - ratio; chnl len/valley length. Outer bank curve radius '.

Though often difficult to measure and understand, there is, nonetheless, an effective relationship between stream flow, sediment, channel slope, particle size, material cohesiveness, and channel patterns. Under prevailing conditions, a given stream reach requires a certain channel length, and the stream will meander precisely enough to make the necessary adjustments (118).

Channel processes tend to place the path or thread of maximum velocity in the center of straight reaches and along the outside of meander curves. The deeper depths tend to develop where bed materials are mobile and the maximum velocity path comes closest to the bank (118).

Sinuosity is important as a descriptor or a measure of central tendency in long term stream adjustments. **Outer bank curve radius** is specific and is used to evaluate the effects of erosional forces on channel stability (114 119). Along the meander, the forces of erosion are thrown against the outside of the meander curve; for example, as the graph shows these forces vary directly as the square of the velocity and inversely with the radius of curvature. Other factors being equal, the meander with the smallest radius will reflect a more difficult problem in stability than any lesser curve or the straight way.



>>>> **Bankfull Width & Depths** - take time to find good bankfull indicators. From width and average depth (from Qbf line); calculate W/D ratio.

Mark Bank X/Y (cotangent) ratio; for the same materials, steep bank sections are more erosive than gentle bank slopes.

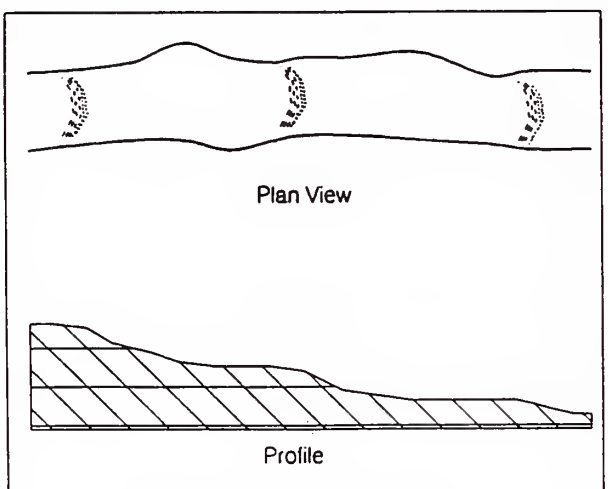
Width/depth characteristics reflect stream adjustments from the relative rate of erosional processes affecting channel bed and bank stability. One indication of watershed erosion problems is the tendency toward wide, shallow channels. Deeper channels have more to offer in terms of diversity for aquatic life.

One obvious factor in bank stability is the slope of the bank itself. The angle of repose is terminology for the angle at which a pile of material will remain stable. The angle of repose increases as the material either gets larger or more angular; and decreases with saturation or the presence of non-cohesive layers such as a sand lens. Vegetation adds extra strength and allows a bank to stand firm at angles greater than that of the material itself. That is why the loss of vegetation is so often accompanied by accelerated bank erosion.

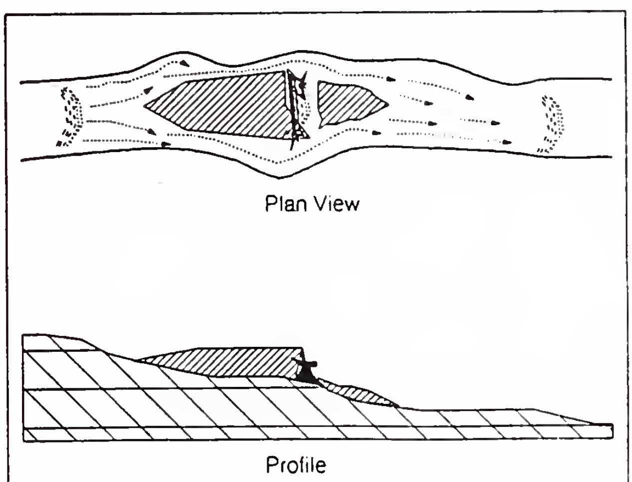
>>>> **Channel Deposition** - % reach with point bar, side bar, mid-channel bar, islands, blocks & cutoffs, tributary delta bars, or pedestals (bank remnant). Count jams that block more than 1/4 Qbf stage.

Erosion and deposition studies are usually more relevant for aquatic conditions than studies of sediment transport (93). Changes in bed elevation and particle size distribution of bottom materials are of particular interest since they tie directly to the problem of antidegradation. Think of deposition in the context of the whole watershed; if more sediment is generated than stream power can move through the system, it stacks up. The stack up cycle includes a negative feed back loop: deposition creates more bank erosion and lateral migration, which leads to more deposition.

When logs, rocks, roots, stumps, or other debris cause discontinuity in stream gradient, they will accumulate sediment. The upstream end of such deposits are frequently marked by breaks in channel gradient, differences in particle sizes of bottom material, and differences in composition of bottom materials. The jam raises the level of the stream at high flow and may accelerate bank erosion.



Pool and Riffle Sequence



Debris Jam & Sediment Trap

>>>> Select features that create **Bed Stability** and record rock size (mm) & major elements of stable lwd.

There are 2 points here that apply to coarse bedded-streams. First, changes in channel shape and structure, including sequences of riffles, pools, runs, glides, scour pools, and boulder cascades, mainly happen when flow events are high enough to move the channel bed coarse fragments. Because riffle bars represent the first material dropped after a high flow, they contain assortments of the stream's largest particles. Current experience suggests that the size of riffle material is a good measure of bed stability and reflects the stream's durability to maintain geomorphic equilibrium under climatic variations (120).

Second, the risk of serious channel stability problems accelerates if flows capable of bed scour or bank erosion become more frequency or if there is a substantially greater sediment supply. The initial channel response to more stream power or more sediment loading is to reduce bedform roughness, usually by filling pools with sediments. Subsequent channel adjustments include increasing the extent and number of depositional areas and riffles, with corresponding changes in width, depth, meander patterns, or longitudinal profile. Taken together the result is fewer and shallower scour pools, loss of stable woody debris, and loss of habitat diversity. (110)

Other things being equal, the risk of bed stability problems, and the likely effects on habitat depth and substrate, can be inferred from a comparison of riffle material data from appropriate reaches. From a watershed perspective, riffle d84 data on several stream reaches suggest spatial distributions of past sediment history: for example, old sediment slugs tend to even out as they move down stream, whereas new spills tend to decrease d84 as you go upstream with abrupt changes to larger d84s above the sources. Systemwide low d84s (compared to reference) indicates long term active sediment sources (121).

\>>>> **Banklands** - Mark the bank **material origin** - residual, glacial, mass movement, terrace or lake deposits, or a jackstraw mix of large woody debris and soils as might be found in an area of beaver dams or land slides.

Bankland Slope- % slope of non-bedrock mtrls above the outer bank curve.

Banklands are an in-channel source of sediment as well as the site of lateral migration. Stream power over its long history has come against the banks. The ability to resist erosion is important knowledge about geomorphic processes. It concerns the T-Walk because well protected banks provide diverse habitat and support for stream health. It also influences stream recovery time.

The origin or process by which the banks were built is important because of the expected size distribution, the angularity, the degree of sorting, the presence of layers, and the amount of silts and clays. For example, Residual materials tend to be angular and gravity sorted colluvial deposits; Glacial materials tend to be rounded and randomly mixed; while Terrace deposits tend to be rounded and laid down in layers of transported materials. These differences may appear to be too subtle to worry about, but they effect channel vulnerability to erosive forces. For example, bank materials that are rounded and contain little clay are substantially more erosive than angular material with clay.

Hillside slope is often a critical factor in generation of mass failures. For example, WRENSS chapter 5 (122), in part, uses these slope classes to rate mass failure risk.

Risk Class	Debris Avalanche	Earthflow
low	< 55%	< 27%
medium	55 - 67%	27 - 58%
high	> 67%	> 58%

\>>>> **Downcut depths** (ft) - measure from channel bottom to 1st bench where flows will no longer be confined. If there is a 2nd bench, flag & note height from its toe to top.

How deep the channel is cut is a critical question. Rapid downcutting from gully processes or increased stream power leaves normal bank vegetation weakened and undercut. The quality and strength of streambank vegetation provides bank stability and the physical support for habitat created by undercutting. When bank vegetation decreases, the banks erode too rapidly and slough off into the stream. Normal stream power from bankfull flow then erodes raw banks with enthusiasm and accelerates sedimentation damage.

\>>>> **For Stable length** (% reach length), check the straights and outside curves for bankfull indicators; what % are aged and well marked, what % are raw site? In evaluating vegetation -- count only durable and/or fibrous root systems and large structural features. Look carefully; banks with new instream features or newly grassed conditions may still be unstable.

Instability triggers - Beaver; high flows (& dam operation & floods); burns; farming; grazing; logging; jams; mine & road side cast; off-road vehicles; pipe (easily sugared, piped, sand lens); head wall; head cut; snagging; overbank flows; seeps & slumps; debris avalanche.

Time to bring some pieces together. The **Stable Length** is an integrator of several factors: flow velocity in relation to channel materials, curvature or meander radius, flow depth, bank back slope, and bank vegetation (114 115 123).

Looking for causes of instability can be difficult; sometimes the obvious is the cause and sometimes not. Stream processes are constantly at work and there may be signs of stream adjustment or local knowledge that can be helpful. The point is to understand the stream system well enough to identify the causes, correct the problems, and anticipate future trends and consequences.

That last sentence is a long term goal that is both difficult and time consuming to achieve. If you are just beginning to work on this problem and need an easier starting place, then you might try this sequence:

First. Will the coarse bottom material in the thalweg prevent down cutting?
Stability can be provided by an armor of coarse material. Without being fussy, the armor size can be estimated from the surface velocity at bankfull over the thalweg: d (mm) = (vel'/s)^2. For example, if surface velocity is 5'/s, then armor material greater than 25mm would likely be stable.

Second. Is the thalweg position being shoved to the side?
Look to see if there is a growth or transfer of depositional material toward the thalweg. In particular, look for a developing shift in size or coarseness on mid-channel or point bars that tend to force flows out of the existing thalweg. As the bar material becomes more resistant to erosion, the downstream opposite bank is subjected to increased attack.

Third. Will the banks remain stable with the expected thalweg changes?
Look to see if the toe of the bank is being undercut and steepened or if vegetation is being undermined that will cause the bank to collapse. Go back to the list of instability triggers and see if any of these now apply.

>>>> <u>T-Class</u> (Thalweg stream and bankland regimes) - includes physical process factors important for maintenance and restoration of water quality. **T-Class** is an open ended classification designed to incorporate existing & potential typic model interpretations. Make **T-Class** specific; code unusual subsurface materials, bimodal distributions, and equilibrium modifiers.

The ability to confidently predict conditions supporting physical, chemical, and biological integrity and associated stream system thresholds is a major asset. Monitoring is expensive and hard-to-come budgets can only be stretched to cover with models and extrapolation from similar situations. Thalweg Classes (T-Class) are designed to aid in the extrapolation and prediction of stream system responses stemming from physical interactions among sediment and water flow variables.

T-Class uses a generic, somewhat mechanical, open ended nomenclature for geomorphic equilibrium, channel materials, and bankland characteristics. Field technicians may expand the basic code structure to incorporate shifts in equilibrium, unusual surface and subsurface particle size distributions, or conditions of channels-within-channels.

It is particularly important to identify major stream system processes that are, or appear to be, out of equilibrium. Restoration efforts must start by correcting equilibrium problems in order to be effective and not just a laundry list of treating symptoms.

The Rosgen stream types are valuable because they are based on field experience and can serve as typic models for average flow and sediment regimes (109).

>>>> **<u>Thalweg Standard</u>** (T-std) - defines conditions of Robust health possible for the study reach and provides the necessary CWA goal comparison. It is essential to match the **Thalweg Standard** to project conditions for valid comparisons. If Robust stream health conditions exist, then use 'before/after' or 'above/below' comparisons to determine Stream Health.

Thalweg Standard equates to the standard of comparison selected for the site under review. Under EPA guidance, such references are to be an objective, comprehensive, and ecological definition of long term natural aquatic ecosystems as a base to evaluate conditions, refine standards, help prioritize improvements, and classify streams by capabilities rather than by existing conditions (124 125).

As a practical matter, functional or structural disorder can only be shown by comparison with suitable reference sites. Analyses must be able to show cause and effect, separate out natural variability, and demonstrate expected natural conditions. It is essential that good reference sites be selected so that the monitoring does not underestimate Robust Stream Health conditions and downplay stream damage. For example, do not select references sites where:

1) non-point pollution sources contaminate most of the water body; or
2) modifications affect the channel, shoreline, or bottom substrate; or
3) several point sources occur at multiple locations; or
4) habitat characteristics are fundamentally different.

To effectively use the stream health rationale, a technician must be able to confidently select a Thalweg Standard, show stream health, and plan appropriate action. Eventually, the State water quality agency will serve as a clearing house for reference sites; however, in the absence of such documentation, technicians need to take a hand in creating enough of a reference reach database to support their conclusions regarding stream health. While this requires an effort, it is not a multi-million dollar campaign only available to research or those truly inspired. Creditable results are easily possible within the scope of resources currently used for NEPA planning (41 42 126).

>>>> Record the name, **T-Class** at equilibrium, and **Tarzwell Substrate Ratio** for the Thalweg Standard. If **T-Class** is different, then select an off-site Thalweg Standard with the same T-Class.

Mandatory. Identify the T-Standard (including T-Class, and Tarzwell Substrate Ratio) that reflects the long term natural conditions for the site under review. Under the best of circumstances, a notebook of T-Standards, complete with pictures and full descriptions, will eventually be available. In the meantime, the T-Standards will likely be generated locally by the technician from comparisons of 'above' or 'before' conditions.

T-Walk assumes that stream physics and biomass production will continue to be major cutting lines for the application of T-Standards. The T-Class and Tarzwell Substrate Ratio associated with a given T-Standard are chosen to reflect long term geomorphic equilibrium and basic food production, respectively.

>>>> If Robust conditions are absent, then antidegradation is also at issue. Record the existing **T-Class** and **Tarzwell Substrate Ratio** that defines the antidegradation limits.

If the stream is already less than Adequate Stream Health, antidegradation requirements prevent any further decline:

- The impact generated by one land use is binding on another;
- the normal 10% leeway in the Robust Stream Health is not available; and
- the installation of management support facilities are limited to those covered by a permit or that cause no net deterioration; (i.e. production lost by a new activity is compensated by improving another reach section.

Reviews that include antidegradation concerns and degraded streams can be handled by two sets of entries; one set for natural condition and one set for the currently imposed antidegradation floor. If the existing T-Class is out of equilibrium, report both the expected equilibrium T-Class as well as the T-Class as it now exists; this helps keep track of trends.

The antidegradation floor rationale also applies to Tarzwell Substrate Ratios. For example, say a Tarzwell Substrate Ratio of 50 is expected under natural conditions and the current TSR is 20 caused by excess sand. The floor is 20 and additional activity can not further reduce the reach's TSR. This does not stop the construction, but it does require enough stream restoration to at least keep the TSR equal to 20.

>>>> **T-WALK** study identification & date - make it clear; name the **Watershed** folio used to store such data and cross file any **Samples & photos**. Do it well; to quickly find data & use for later analyses makes you look ready for promotion.

T-Walk Study site ID needs to be site specific so the data place is not lost. 'Not lost' is the operative phrase; much too much data collection and analysis have been simply discarded or obscured to the point that the data is worthless. The past management prerogatives that allowed the discard have been swept away in a storm of judicial review and litigation that demand full-disclosure with high quality and consistent data. All data collection and analysis efforts, including T-Walk, must be closely tied to the long term needs to supply legally defensible information for administrative records, fulfilling agreements, responding to lead agencies, substantiating legal claims, and providing accountability.

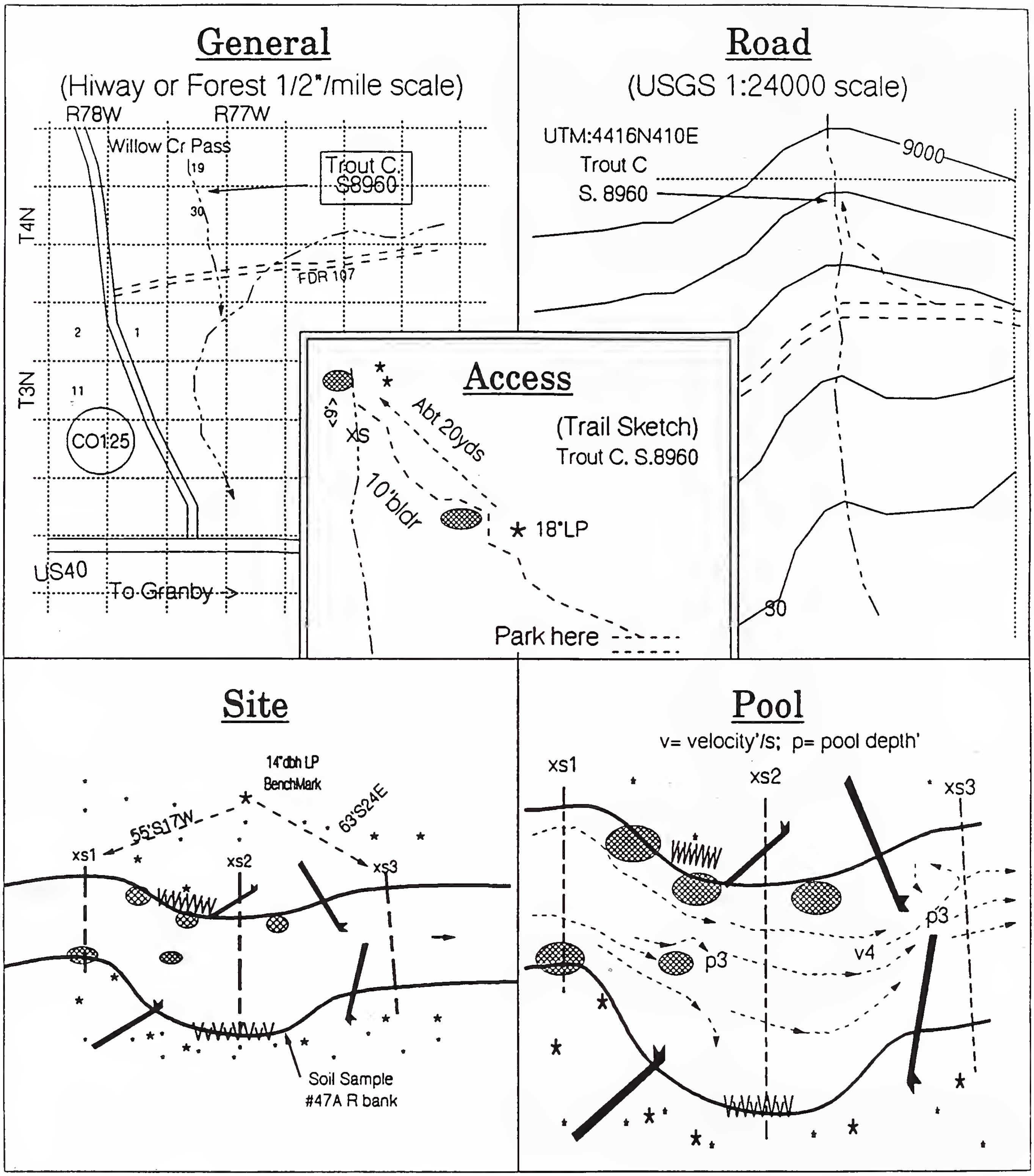
In part, study sites need to be field monumented in ways compatible to the decision time frame. For example, a concrete benchmark would provide field location for 50 years as might be necessary to document a water right; whereas, a steel rebar or wooden stake wouldn't last that long. The important point is to think ahead so today's efforts will contribute to future understanding.

Current experience suggests that finding a previous field plot requires both a structured naming protocol and a series of maps or sketches. The acrostics "SITE" and "GRASP" are used to help remember the factors and sequence:

- SITE name as N4416 E410; Trout Creek; South 8960.
  - S = map Square such as Universal Transverse Mercator (UTM); Lat/Long; or Township, Range, Section. Try UTM first; the 1:24000 topogs and orthophotos have 1km tics & the 1:50000 county topogs have 5km tics. For a label, use the lower left UTM corner because UTMs increase going north and east. Be aware that longitude decreases going east.
  - I = Identification sequence of major to minor stream name such as Willow Creek UNT (unnamed tributary). Include the watershed code, if any.
  - T = Trending direction of downhill or flow will help separate out nearby sites. Use at least the 8 compass points.
  - E = Elevation of low end of reach picked from a 1:24000 topog is adequate. Try using a field barometer adjusted to local benchmarks.

- GRASP sequence of general, road, access, site, and pool maps.
  - G = General vicinity -- prefer 1/2"/mile scale with towns and roads;
  - R = Roads -- prefer 1:24000 topographic with roads, trails, and streams;
  - A = Access sketch of how to get there including distances and landmarks;
  - S = Site sketch of benchmarks, cross-sections, and sample points; and a
  - P = Pool sketch of stream features including pools, rocks, and bars.

Cross index T-Walk back to the appropriate watershed folio, so any data, analysis, forms, photographs, laboratory data, and maps can be consolidated for long term information access. Please do not rely on computer data bases; they - for all their great expense - are temporary.


General
(Hiway or Forest 1/2"/mile scale)
R78W
R77W
Willow Cr Pass
19
30
Trout C.
S8960
FDR 107
T4N
T3N
2
1
11
CO1:25
US40
To Granby ->
Road
(USGS 1:24000 scale)
UTM:4416N410E
Trout C
S. 8960
9000
30
Access
(Trail Sketch)
Trout C. S.8960
Abt 20yds
XS
10'bldr
18"LP
Park here
Site
14"dbh LP
BenchMark
55'S17W
63'S24E
xs1
xs2
xs3
Soil Sample
#47A R bank
Pool
v= velocity'/s; p= pool depth'
xs1
xs2
xs3
p3
v4
p3

>>>>   <u>**Diversity Screen**</u>- (late season (low flow) and fair weather conditions)

The diversity screen is CWA S404 directed and takes a broad look at aquatic life and selected terrestrial and aquatic habitat features as it supports ecosystem diversity. T-Walk is not subtle; its purpose is problem selection and finding out what, if anything, has to be done for stream restoration. Given 3 distinct levels of diversity -- within-habitat, between-habitat, and landscape -- T-Walk focuses on between-habitat diversity and these environmental gradients (127).

The T-Walk diversity screen is not in competition with any detailed macroinvertebrate analytic tool or similar professional activity. However, it can be used to help locate likely candidate sites for further analysis, and thus save time in picking detailed study sites.

>>>>   **Riffle Insects** - pick up 10 fist size rocks (or equivalent) from riffle areas. Study each rock with a hand lens and record the total of all nymphs & larvae for the 10 rocks. Record presence of mayfly and stonefly nymphs, and caddisfly larvae & cases. Mayflies have lateral abdominal gills (back end looks fuzzy w/ 2 or 3 tails) & stoneflies do not (2 tails clean outline). Mark all characteristic case shape & material: organic boxlike or cones; sand grain flat, round, or spiral; loose "scaffold" of leaves, twigs, or pebbles; and webs, socks, or trumpet-like nets.

The 10 cobble count procedure tends to select free-standing rocks from riffle habitats. Such sampling favors macroinvertebrates that can either hang on or protect themselves from relatively rapid flows. Several common families of mayflies, stoneflies, and caddisflies, likely to be represented in such a riffle sample, are also sensitive to chemical changes (128 129).

The Kansas Biological Survey sampled stream insects in areas of acid mine drainage. The Survey supports the notion that species of mayflies, caddisflies, and stoneflies are clean water animals and make a good test for metal pollution impacts (130). If the three groups are present in reasonable numbers, then water column chemistry is probably in good shape.

Some authors separate pollution tolerance at lower taxa levels. They suggest substantial differences of tolerance to chemical and organic conditions within orders (groups of families), within families (groups of genera), and within genera (groups of species) (128). So the T-Walk progression of sensitivity

-- caddisfly >> stonefly >> mayfly --

is a generalization for families likely to be in the riffle habitats sampled by a 10 Cobble Count. For 2 Colorado mountian streams, natural mineralization and mining impacts showed the same progression of caddisfly-stonefly-mayfly sensitivity; however, the response curve was very steep, meaning that once decline started, it took very little extra metal contamination (i.e. 0.2 mg/l Zn) to waste the whole population (131 132).

The groups are also sensitive to severe physical changes. For example, stream channelization may result in the loss of stoneflies even though mayflies and caddisflies are represented (133).

The 10 Cobble Count, as an indication of "reasonable numbers", is taken in the riffles. The total insect count scale gives estimates of population abundance, but they are not statistical parameters. A real population study will be adjusted for the seasonal hatches, need a large sample size, and have a high coefficient of variation. Translation: please don't add up the counts, divide by a number, and call it population. Also, be aware that elevation just naturally limits populations. For example, a 10 Cobble Count of 16 at 9000 feet would indicate a problem; but at 11,500 feet, probably not.

An extensive computer simulation study of several diversity and community structure indexes showed that esoteric computations (and data sets) do not necessarily give better results than a simple count of taxa for showing impacts (134). Therefore, T-Walk does not operate from a species diversity rationale.

>>>> **Pools** - record flat & pool water %, maximum depth, & temperature (optional). For 2' depth and 1'/s velocity, mark all the categories that apply.

Pools in conjunction with riffles provide habitat variety. Pools and the associated habitat quality can be destroyed by excess sedimentation, channel changes, loss of large woody debris, and road construction effects. T-Walk assumes that more and deeper pools, in combination with riffle food production areas, are a basic benefit to any existing fisheries. The % of reach is not particularly critical, with anything from 1/3 to 2/3rds being satisfactory. However, depth of 2 to 3 feet is critical to overwintering adult trout (90 95).

>>>> **Stream bank vegetation** - % total for both banks and what kind: grass, forbs, low shrub (<2'), hi shrub, conifer, or deciduous trees. Roots may be shallow (<Qbf) or deep (>Qbf) with either a sparse or dense root network.

Different riparian species and growth forms contribute shade, cover, and organic materials to the aquatic trophic structure. Land uses, particularly grazing, may cause a shift in growth form toward less desirable aquatic conditions including reductions in biomass, bank overhang, and depth along the shore (95).

Streambank vegetation vigor is dependent on the frequency and degree of use. If the removal of biomass exceeds what the plant can easily recover, then stream protection decreases, banks erode too rapidly, and stream health declines.

The idea is easy to understand; but the results from methods that use the amount of vegetative biomass removed have been impossible to repeat on the same stream reach or with different people -- a obvious bother. Current efforts now include stream bank vegetation roots as a surrogate of above-ground health (135).

In the context of this diversity screen, the basis assumption is that stream banks with deep and dense root systems are likely to be topped by vigorous above-ground vegetation for which the current level of biomass removal is not creating stream health problems. To the extent that root systems become relatively shallow and sparse, the above-ground vegetation is less likely to be vigorous and, therefore, contribute less organic matter to the stream.

>>>> **Shores** - % total for both banks w/ stable bank undercut or vegetation overhang. Record maximum shore depth (at water surface), 0.1'.

Shore condition is a simple and effective way of evaluating land use activities that can modify stream banks or stream bottoms. Habitat loss caused by grazing and road construction and maintenance is common - and obvious when you look.

Differences in shore depth, material, and cover conditions support diversity. Undercut banks and overhanging vegetation are critical habitat for fish. To be of value, the stream banks must be stable and the vegetation close enough to provide both shade and litter to the stream. Stable stream banks that include large woody material, rootwads, fibrous roots, or large rock are great habitat; fish will school along the edge to learn how to catch the wily flycaster.

Shore depth is especially critical to the young of the year. Use normal late season flow as a benchmark for shore depth, undercut, and overhang estimates.

>>>> **Instream vegetation** - % of reach w/ brown or grey fungus scummy mold, filamentous or matted algae, wet wood (branches & >), and rooted water plants. Count Lwd induced pools or flat water habitats in reach, #/660' reach.

The plant and animal life that compose the ever-present, late-season, brown or green rock slimes provide primary production and is a major source of food for many macroinvertebrates. However, current experience suggests that reporting on rock slime would have little value in discriminating stream health conditions.

So T-Walk begins notation with algae, another primary producer, that is a little more uncommon. In reasonable amounts it is beneficial; in large amounts it is detrimental and may generate oxygen deficiencies in warm, low gradient streams when the bloom dies. A grey or white scummy mold or fungus bloom indicates an over load of organic wastes; it is definitely not a good sign for stream health.

Vegetation such as mosses or rooted, floating, and emergent vascular plants, reflect slower water and a suitable nutrient cycle. The presence of instream vegetation supports extensive macroinvertebrate diversity as well as high production rates.

Instream woody material provides physical structure and habitat for a variety of macroinvertebrates and fish. Suitable amounts of woody material is essential to diversity; however, material that interferes with the normal passage of bankfull flows creates long term problems with sediment transport, sediment deposition and accelerated bank erosion. Current experience suggests that 1/4 blockage of stream channels is an upper limit after which damage is expected (99).

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>>>> Stains & precipitates - natural or man made mineral/organics deposits (patches, seeps, or gal/minute flow) w/ white, red, orange, yellow, green, blue, indigo, violet, black colors. Red & yellow will be most obvious; but look carefully - some very toxic materials are not obvious.

EPA's priority pollutant list includes antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Some of these may be present individually or as compounds in seeps or precipitates in streams or wetlands. As water rich in dissolved oxygen and carbon dioxide percolates through the mantle, it reacts with primary ores and surrounding rock to produce new compounds. If iron pyrite is present, then sulfuric acid is released, and the chemical reaction time is accelerated. Limonite, a rusty colored iron mineral, is a common indicator of this chemistry. Be aware that any other metals will be released in the process and be associated with the reds, oranges, and yellows of the iron oxides. With sufficient copper, stains tend to be bright greens and blues or brilliant luster ruby-red. Stains from other metals range in color from white to black, metallic to dull surface, from opaque to dense.

The priority pollutant list also includes organic chemicals with names hard to pronounce and impossible to spell. Hydrocarbon chemicals for industrial use are very complicated and may be present as buried 55 gallon drums or just dumped on the ground. Note the presence of such material and call for follow-up monitoring with the specialized sampling procedures and analytical skills.

Anything is possible; the purpose of T-Walk is to locate sites of possible inorganic and organic chemical impacts and, if needed, develop a follow-up study to find out how to fix the problem.

>>>> Diversity Screen Interpretation -

If you can not match the stream reach against a **T-Standard**, the next step is to go directly to the Aquatic Life Health Class table, and make a determination. The following table gives you a first cut by focusing on one Diversity Screen parameter at a time. Read across the table and select the likely Reference condition, then down the Site column to match current or expected condition. If they are the same the table shows Robust (R) health. For Sites that are impacted and of less quality than the Reference, the table shows the decline in health. (If Reference 10 Cobble Count = 128, and Site = 64, then read 'D' from table).

The table is a 'best guess' interpretation, so do not fuss over single factors. Look for patterns among the factors that support or confirm a particular Aquatic Life Health determination. However, this step is not an averaging; if an individual factor is clearly controlling, then it determines the health class.

Temper the table's results with what you know of the area, it's recent climate and management history, and expected impacts in the future. Then, if conditions are not what they should be, the limiting factors suggest a beginning for restoration planning. For example, if Shore depth should be 2' and it is only 0.2', one part of restoration might be to fence-protect the bank, add a log along the bank toe, back slope, and plant willow.

Until such time that **T-Standards** are available, the full burden of stream health interpretation will remain with the field technician. The T-Walk Stream Health interpretations are based on limiting factor analyses developed in 3 phases: first, habitat factors and scales known to be important to Robust Stream Health for trout were selected; second, the optimal zone for each habitat factor was selected from conditions expected in the Rocky Mountain Region; and third, the optimal zone for each factor was incrementally reduced to correspond to changes in the Stream Health categories.

Each factor interpretation is structured the same way. The technician makes a determination of what the factor is now and compares it to what the factor should be. If they are the same, Stream Health is robust. If not, then the comparison shows a lesser Stream Health and an indication of the restoration problem. Current experience suggests that the factors, increments, and interpretations will continue to be refined as more people work with the 3 basic questions in Stream Health evaluations:

What is it now?
What should it be?
What needs to be fixed?

The question "What should it be?" is speculative because the "should" is philosophical land ethics that sets short term gains against long term goals. The Clean Water Act is clearly long term; but conversations with field people accentuates the difficulty of identifying what "should" be if the site is already damaged (40 41 42 43 44 99). T-Walk skirts the issue by identifying damage (yes/no) and uses the existing parameter condition to select the health class. This also keeps the attention on what has to be fixed.

Management Information

> "The Committee intends that an overall program of on-the-ground monitoring, coupled with research, insure the sound management of National Forest System lands. .... If research or evaluation establishes that a management system or method is producing impairment of the productivity of the land, such system or method will be modified or discontinued." [6699 USCC&AN 1976].

> "The subject of "nutrient degradation" on forest soils is a matter of real concern. Additional research and more comprehensive monitoring and evaluation ... is a high priority ...." [6699 USCC&AN 1976].

> "The Committee wants to know what waters are in their natural state and where they are located. The Committee wants to know what waters are of the quality which will assure protection and propagation of fish, shellfish, and wildlife. .... The Committee wants information on those waters which fail to meet high quality requirements, where they are located, and the reason for the failure." [3722 USCC&AN 1972].

The first two quotes are from the legislative history of the National Forest Management Act (NFMA) and the last one is from the Clean Water Act (CWA). NFMA carries the term "impairment of the productivity of the land" forward from the Multiple Use Sustained Yield Act (MUSY) and implies that "nutrient degradation" is a part of the definition. MUSY, however, does not define "impairment" other than to incorporate the 1944 Sustained Yield Forest Management Act; the goals of which include "... to secure the benefits of forests in maintenance of water supply, regulation of stream flow, prevention of soil erosion, amelioration of climate, and preservation of wildlife, ..." (16 USC 583).

Reread the last sentence. This is THE LEADERSHIP statement about sustained yield that is retained by both the 1960 MUSY and NFMA. It is clearly oriented to timber production <u>within</u> the context of watershed protection. And that the prevention of soil erosion is a necessary condition of sustained yield.

Is this important? Well, that depends on your personal motivation and "fight or flight" response to resource ethics. Keep in mind that short term economics and resource exploitation will ALWAYS have the money to hire lawyers and consultants to push their claim -- often by simple intimidation. The best way to counter intimidation is to have a sense of what is right, what can be defended, know the rules of the game, and not be cowed into being silent.

It is abundantly clear that achieving the Clean Water Act goal of physical, chemical, and biological integrity is a managerial function (136). It is also clear that the technician needs to provide useful and timely information so that related decisions can be made routinely. The T-Walk advance warning system is intended to be an evaluation and notification to the manager of current and expected stream health, adverse impacts, cost liability for restoration, proposed remedial action, and follow-up monitoring.

>>>> Watershed name and # - local name and agency code (& any sub-wshed #).

The Clean Water Act and cumulative effects as well as State reporting procedures for water quality takes a watershed perspective (137). Include identification of National Forest System watersheds as directed in FSM 2513 and 2542. Also check for site identifications with legal significance, such as water rights or special use permits.

If a new site id is pending, consider the name and code from a 50 year perspective. For example, UTM coordinates, stream name, trending, and elevation would last, but a simple reference to PC-1 is quickly lost.

>>>> Note site vegetation & management prescription.

It is possible that the 40 acre evaluation cell will include several vegetation types and management prescriptions. The history and existing condition for each type and activity generates its own combination of risks and opportunities. A short summary with special notes about past land use will help estimate the likely outcomes from road construction, rest/rotation grazing, mining, clear cut timber harvest, campgrounds, or similar high impact land uses.

>>>> Make local directions & legal location (1"=2000') accurate enough so later visits are possible.

Monitoring systems are effective if - and only if - they produce specific information on sites that can be re-located and verified. This requires a good written record as well as a series of maps showing exact location. The sequence needs to include a general map of towns, watersheds, and land status; a topog map of roads and trails; an access sketch of trails and landmarks; a site sketch of stream study features with bearing and distances; and a pool map of local dimensions, velocities, and patterns suitable to define future changes.

The essential point is to be able to re-visit a T-Walk site, add to the information, and add the results to the watershed folio. Legal location or the use of UTM's provides a uniform base of location. Adding compass trending and elevation to identified creeks can also furnish good field and map location - as was suggested in Site identification discussion.

>>>> Assessment of Stream Health - compares existing with standard natural conditions. Show existing Stream Health Class and predict Stream Health Class in the next 2 years. Abbreviate health classes as - R robust, A adequate, D diminished, I impaired, P precarious, or C catastrophic.

The overriding objectives for monitoring is to reduce vulnerability to personal liability and litigation, reduce losses to the resource base, reduce restoration costs, and reduce loss of future management options. To be effective, the information needs to be both easily summarized and useful through the entire range of biological conditions. Most important, it has to scale both impact and incremental risk from resource use in terms relevant to management.

The term "resource use" means the interaction of human use with natural impacts including drought, wind, insects, disease, fires, floods, and land slides. There is no special category for these natural events because both planning and policy related to natural resource use has been around long enough to incorporate the risk as well as the magnitude of such events.

The descriptive names for Stream Health Class were chosen carefully: first, to be complimentary to similar concepts in other resource disciplines; second, to serve as a scale of management impacts on stream conditions; and third, to use nomenclature that carries a quickly understood value judgement. Below is a brief description of the transition among Stream Health Classes:

Robust Stream Health suggests that no resource use changes are required; that all systems are in balance; and that natural processes are effectively assimilating management generated effects.

Adequate Stream Health suggests that the resource damage is lawful and within the permitted conditions; that only a few areas are lost to production.

Diminished Stream Health suggests that natural systems are stressed in ways that require resource use to back-off before major damage is done.

Impaired Stream Health suggests that natural systems are clearly pushed too hard; that damage is substantial and recovery will be slow.

Precarious Stream Health suggests that natural systems have been pushed to the limit; that recovery will be very slow and expensive.

Catastrophic Stream Health suggests that natural systems have been pushed beyond their limits and the existing site quality has been destroyed. The management phase is now concerned with failure and liability with substantial resources going to on- and off-site damage control.

Since the Clean Water Act is an accountable managerial function, the Assessment of Stream Health is a key item and reflects a 'bottom-line' measure of how current conditions stack up against the legal goal of ecological integrity. The technical job is to evaluate the existing and expected 2 year Stream Health Class based on descriptions of ecosystem stability, diversity, and production.

>>>> <u>Profile of Noticeable or Expected CWA Impacts</u> - circle existing conditions for each CWA S*T*O*M*P*E*D impacts; show any trends with an arrow. Summarize impact source, i.e. 'badly rutted roads, no waterbars'

In the 1970's the EPA contracted Battelle Columbus Laboratories to make an expert analysis of current and future pollution problems for the purpose of guiding EPA's research and development in pollution control efforts (72). The analysis was structured to reflect complexity and seriousness inherent in industrial production, environmental contamination, and societal trends. Well over 50 problems were reviewed, combined into sets, then finally ranked. For the "top ten" listed below, notice that they cut across all political boundaries, land ownerships, and exist as multi-media land, air, and water problems:

Rank	1	Impacts of New Energy Initiatives
"	2	Geophysical Modifications of the Earth
"	3	Trace Element (Metal) Contaminants
"	4	Proliferating Hazardous and Toxic Chemicals
"	5	Emissions from New Fuels, Additives, and Control Devices
"	6	Disposal of Waste Sludges, Liquids, and Solid Residues
"	7	Critical Radiation Problems
"	8	Fine Particulates
"	9	Expanding Drinking Water Contamination
"	10	Irrigation (Impoundment) Practices

For each problem, ecological insults or stressors were identified. The definition used by the team for ecological stressors included any chemical elements or compounds, biological agents, or physical attributes that reduces the ecosystem's ability to maintain itself in a natural condition of niche partitioning and population dynamics.

Many individual stressors were identified. Fortunately, for this purpose they could reasonably be grouped into seven basic dimensions of long term ecological stress. The acrostic "STOMPED" should help you remember the full set as:

S* Sediment regimes in air and water.
T* Temperature regimes in water.
O* Oxidation regimes on land, in air, and in water.
M* Metals contamination of ecological process.
P* Poisoning of ecological process.
E* Equilibrium shifts in geomorphic process.
D* Dissolved chemical regimes in water.

The purpose of the profile and the problem list is to concentrate follow-up remedial and monitoring efforts on real problems and to avoid trivial pursuits by just doing the easy ones. That you are less likely to waste your time by going after the real problems can be paraphrased by this bit of street wisdom: you can't run with the big dogs, if you piddle like a puppy.

>>>> **Synopsis and necessary response time** - summarize problems; show target date(s) for any emergency action, or remedial work needed to prevent further damage to facilities (including roads) and water courses.

There are two basic questions: fix what? and how soon? Pay particular attention to emergencies that threaten life or property. But, remember that State and Local officials have the responsibility for protecting life and property as well as the maintenance of law and order. (The Forest Service will engage in emergency operations only if there is an imminent threat to life or property which must be met through immediate use of FS resources).

While on the subject, please don't take chances. Treat all situations with caution. You are NOT required or expected to do work for which you are not trained. Toxic, Hazardous, or Inflammable Materials may be involved: so avoid contact with skin, eyes, or clothing; stay upwind, avoid fumes, dust, or mists; and don't smoke.

Some typical hazards with short or emergency response time includes avalanche, caustic chemical exposure, chemical spills and releases, dam failure, explosion, fire, flash floods, food supply contamination, public health vectors, land mass failure, toxic fumes, or water supply contamination. Some typical hazards with a seasonal response time includes channel blockage, channel capacity reduction, accelerated erosion, fisheries impairment, accelerated reservoir sedimentation, or road and bridge damage.

Watershed contingency plans are required to take care of oil and hazardous chemical spills. There are also specific requirements for areas used for drinking water supplies. Check the contingency plans for the watershed under consideration.

>>>>   Expected CWA Restoration Costs - Benefit Lag Time

>>>>   Failure to meet CWA responsibilities -- as shown by a Stream Health Assessment (Existing or Expected 2 year) of Diminished, Impaired, Precarious, or Catastrophic -- triggers a stream recovery evaluation for each of the CWA S*T*O*M*P*E*D* impacts that fail the 'Adequate' level. **Benefit Lag Time** measures time-out-of-service for resource development economics until recovery of statutory environmental conditions.

Any stream condition less than Adequate Stream Health increases the vulnerability to litigation and court imposed remedial action. Watershed recovery is addressed by defining the time needed to lapse before further activity is advisable and the costs to restore stream health. These costs reflect court enforceable sanctions and therefore the downside risk for poor project execution.

Following such a statement, there is always a response of 'so what'. The problem is one of information; generally, court awards or EPA administrative actions are not front page news, - and if it is local - it is quickly brushed aside. But there are a few cases; and these serve as reminders of the real liability.

For at least one major set of federal planning guidelines, project related economic benefits cannot be counted until environmental standards are also met. Benefit lag time embodies the concept of time out-of-service and is counted as time interval, from year 0 to the beginning of acceptable environmental conditions. Nor can the issue be sidestepped by 'forgetting' to include the real costs of resource damage and appropriate mitigation; existing case law suggests that flawed, unbalance economic analysis is 'not compelling' (701 F.Supp 1473).

Given the rules of economic analysis and discounting; both future worth and net present value analyses favor plans with zero benefit lag time. By maintaining Adequate and Robust Stream Health, projects are ready to go on line.

>>>>   For the 'with' and 'without' plan condition, develop estimates based on recovery of Robust aquatic life health class and long term productivity.

The "without plan" is an estimation of the most probable future condition including direct, indirect, and cumulative effects. It includes an inventory of identified problems, opportunities, and associated quantity and quality of water and related land resources. Under Water Resource Council 1983 guidelines, it is the baseline from which to forecast planned effects and is synonymous with "No Action" as used in NEPA regulations (138).

The "with plan" consists of a system of structural and/or nonstructural measures, strategies, or programs formulated to alleviate specific problems or take advantage of specific opportunites. If conditions are less than Adequate Stream Health, the goal of the "with plan" is recovery.

>>>> Benefit Lag Time - 1) identify activities that aggravate the problem;

Successful watershed plans are developed within the context of natural ecosystem processes and limits; focuses on watershed functions and performance, not symptoms; compares existing conditions with healthy conditions; locates sites of accelerated runoff and erosion; prioritizes high risk situations; and defines management changes necessary to sustain improvements.

Successful watershed projects focus on the whole watershed, treat chronic management problems, emphasize land treatment, and restores dynamic equilibrium to channel shape, slope, and capacity. Successful activities increase ground cover, increase soil water storage, reduce on-site drainage density, and dissipate concentrated runoff.

>>>> ... 2) estimate recovery (years) for S*T*O*M*P*E*D Impacts.

The literature on stream recovery, at least in the way it applies to T-Walk, is skimpy. The studies that do exist tend to be data intensive, statistically complex, and/or lack a procedural rationale that can be easily applied to rough terrain. What is really needed is for treatments to be totally effective, low cost, long term maintenance free, naturally appearing, and easy to install in rugged terrain with poor access and lots of winter weather.(!)

Since the economic difference in net present values between "With Plan" and "Without Plan" drives the need to estimate recovery rates, even a rudimentary process is valuable. T-Walk starts with a sediment recovery guide for both benefit lag time and restoration cost. The intent is to try to find a procedure that will survive field verification and serve as a guide for restoration of temperature, oxidation, metals contamination, poisons, or dissolved chemicals.

Equilibrium shifts and bank stability problems reflect stream physics at the watershed scale and will need to be addressed at that level. Currently, the S* sediment recovery estimate includes an approximation of bank stability and how it effects stream recovery.

>>>> Guidelines:
>>>> S* Rcvry, yr = Storm Runoff Control + Bank Stability + Sediment Flush

Most agencies have written official policy about land stewardship and the protection of soil and water resources. However, the real policy is the one that gets implemented; and field evidence provides the only compelling evidence of whether official policy is being implemented or not. T-Walk uses storm runoff control and bank stability to provide field documentation of results of land stewardship. Both measure the impact of long term land management strategies. Both can be used to show both direct on-site effects as well as indirect watershed effects.

The time it takes for a stream to flush excess sand through a given reach identifies a rate of change in cumulative effects. There are natural differences in stream power and bed materials; consequently, some reaches are more susceptible to sediment damage than others. The ability to flush sediment reflects several stream physical processes that can be used in project design to help restore stream equilibrium and avoid sediment related cumulative effects.

>>>> - Storm Runoff Control = the greatest time for a,b, or c where
a = LFH ground cover recovery, (use LFH G. Cover Recovery Table);
b = road erosion control, (use R. Erosion Recovery Table);
c = gully & rill stability, (best guess or LFH G.Cover Recvry Table).

The time it takes for site erosion, road erosion, and gully erosion to slow to acceptable rates are expected to be concurrent events. The main exception is the contribution of roads or open sites that aggravate rill and gully problems; these sites have to be fixed first, then the rills and gullies.

Storm runoff control combines several phases of Best Management Practices as might come from the State, or Soil and Water Conservation Practices as might be contained in land use plans for a Federal agency. It's basic purpose is erosion control, road erosion control, and gully erosion control (139).

>>>> Bank Stability = Extra time as needed for stability after Storm Runoff Control recovery. Extra time is likely for sediment or flow equilibrium shifts, such as sediment spills, water yield increases, or changes in stream flow peak or bankfull duration. Otherwise, assume no extra bank stability recovery is needed.

Natural recovery of bank stability is dependent on achieving watershed equilibrium. T-Walk assumes that if bank stability problems are localized and not the result of upstream conditions, land use activities designed for good storm runoff control conditions on-site will also provide localized bank stability. If stability problems occur because of accelerated sedimentation or flow, then natural recovery will be greatly delayed and will likely require bank toe hardening along with revegetation.

The complexity of bank erosion control is not all technical. There is major political infighting going on about the legal status of the stream courses themselves. T-Walk takes the perspective of the Clean Water Act, but there are other laws and politics that view stream systems as merely operational

components for the convenience of water resource development. Issues of this kind are finding more time in court.

>>>> - Sediment Flush = If Storm Runoff Control &/or Bank Stability need recovery time, then add Sediment Flush to the total. Otherwise, it reflects recovery time from a single massive sediment spill.

Sediment flush reflects the time it takes for the stream to move the excess sand through the system and return the stream bed to natural conditions. Upon occasion, sediment flush is perceived as a way for the stream to recover from excess sediment. This is true for stream reaches that have sufficient energy; but since sand does not evaporate, it remains in the system as a public problem. This is the heart of the sediment related cumulative effects issue.

T-Walk takes the perspective that flushing may move the problem, but the basic responsibility remains the same. T-Walk calculates the time it takes to move sand through a given system; the value is to concentrate restoration efforts where natural processes will help reduce costs or speed recovery. The objective is to remove excess sediments, rather than let them go down stream.

```
>>>>>        Sed Flush Rcvry, yr = 18 / (Grd * Cmp)      where:
             Grd % = stream gradient,%, (range 0.5% to 10%);
             Cmp = Competency of Bank Matrls & Assc. Vege; (see Tbl)
   Ex: 20% LFH g.cvr, 0.3'LFH, 90% effect. buffer, 2yr road eros ctrl plan.
       No active gullies; 2% stream grade; Glacial cobble w/ brush.
       Stm RO Cntrl = greater of LFH g.cvr =20, road = 9, or gully = 0
       S* Rcvry = (SRC= 20)  +  (BS= 0)  +  (SF= 11) = 31 years
```

This simple formulation reflects a very small data set combined with extensive seat-of-the-pants extrapolation from numerous stream bank visits. The point of focus is the stream energy and the competency of stream bank material and vegetation to resist erosion. Sediment flush time decreases with steeper stream gradients and tough, hold-it-together, stream banks. There are two reasons for continued use of the formula: nothing else is yet available in the T-Walk context, and so far, the answers have been useful to the restoration question.

Competency* of Bank Materials and Associated Vegetation

Bankland Regime	Bank Protection Raw	Grs	Brs	Trs	Bankland Regime	Bank Protection Raw	Grs	Brs	Trs
Gb	.80	.87	.91	.94	Rr	.89	.94	1.00	.99
Gc	.69	.75	.79	.81	Rb	.86	.91	.96	.96
Gg	.50	.56	.65	.62	Rc	.69	.76	.84	.85
Lf	.27	.33	.45	-	Rg	.48	.55	.66	.67
Jf	.31	.38	.40	-	Rs	.23	.31	.38	.40
Mb	.70	.74	.83	.81	Rf	.24	.31	.41	.43
Mc	.54	.60	.69	.66	Tc	.55	.64	.75	.77
Mg	.37	.46	.54	.53	Tg	.40	.52	.63	.65
Ms	.17	.27	.31	.33	Ts	.19	.28	.37	.40
					Tf	.21	.30	.38	.40

* Rr (Resid bedrock well fractured, colluvial soils) with good brush cover had greatest competency (C=1); all other Bankland Regimes were compared to Rr brush.
G = Glacial; L = Lake; J = jackstraw (like a filled in beaver dam);
M = mass movement deposits; R = Residual materials; T = Terrace deposits.
See channel material size codes for r, b, c, g, s, f.
Ex: terrace deposits of cobble covered with willow shows competence of 0.75

The "Competency of Bank Materials and Associated Vegetation" is little more than an educated guess; the table values show more accuracy (.xx) than they should. As you use the values, round them off to nearest 0.1, and think about what the results suggest rather than what they predict. There has been no further study of bank competency to improve (or disqualify) these values. However, the notion persists that it takes substantially more time for a sediment flush in streams with highly erodible bank material than it does for those with protected banks.

LFH Ground Cover Recovery, Years* (140).

LFH depth'	Ground Cover % <20	20	30	40	50	60	70-99%
0.01	106	54	35	19	8	2	0
0.05	92	47	30	17	7	2	0
0.1	78	40	26	14	6	2	0
0.2	55	28	18	10	4	1	0
0.3	38	20	13	7	3	1	0
0.4	27	14	9	5	2	1	0
0.5	19	10	6	3	2	0	0
0.6	13	7	4	2	1	0	0
0.7	9	5	3	2	1	0	0
0.8	7	3	2	1	1	0	0
0.9	5	2	2	1	0	0	0
1.0	3	2	1	1	0	0	0

* LFH Ground cover recovery, yr = (110 * e^-3.5*LFH) * (1 - 2X + X^2)
where LFH = litter, fermented and humus depth (ft)
X = (Grnd Cvr%/70); if 70% or more, Recvry = 0 yr.
(detrimentally compacted areas are not Grnd Cvr).
Ex: 80% bare soil; undisturbed LFH of 0.5' (6" duff). Rcvry = 10 years

During the 1950's, the FS worked with other agencies, to develop hydrologic methods that could be used in soil and water resource planning; these were published in Forest Service Handbooks. T-Walk recognizes the vast amount of field experience and insight that went into the rationale for the methods used to analyze hydrologic condition, long term recovery, and infiltration. These became the starting point for the "Ground Cover Recovery, Years" table (70 71).

T-Walk uses LFH depth as a measure of site recovery potential and % ground cover as a measure of land use. Note, first, the general pattern that recovery is slower if conditions start with either poor sites or large amounts of bare soil; and second, recovery is often measured in decades and half-centuries.

Vegetative cover and litter protect the soil and provide organics that promote loose and friable soil structure. Therefore, land use practices or natural events (i.e. fire) that remove major amounts of vegetation, or accelerates the loss or oxidation of litter and humus, or creates excessive soil compaction, often drastically reduces infiltration rates and surface depression storage. Total storm volume and peak rates will increase to the extent that infiltration is the limiting factor and overland flow the dominant storm flow runoff process.

Humus depth increases with age of the stand until an equilibrium is reached. Depths of 1.0' are not uncommon, but 0.5' is about average for old and protected forest sites. Forests on unstable soils or those with a history of relatively frequent fires develop much less than 0.5' of humus with, perhaps, 0.3' being a realistic goal for long term forestry.

Road Erosion Recovery, Years*

Sediment Yield%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	1	1	1	2	2	2	3	3	3	3	5
2	2	3	5	6	8	9	11	12	14	15	22
5	4	7	10	13	16	19	22	25	28	31	46
10	5	9	13	17	22	26	30	34	38	43	64
15	5	10	15	20	25	30	35	40	45	49	74
20	6	11	17	22	27	33	38	44	49	54	81
25	6	12	18	24	29	35	41	47	52	58	87
33	7	13	19	25	32	38	44	50	57	63	94
50	7	14	21	28	35	42	49	56	63	70	105
67	8	15	23	30	38	45	53	60	67	75	112
85	8	16	24	32	40	48	55	63	71	79	118
90	8	16	24	32	40	48	56	64	72	80	120
95	9	17	25	33	41	49	57	65	73	81	121
99	9	17	25	33	41	49	57	65	73	81	121

* Recvry to annual 0.3 cf/a; ln(0.3/(0.4Syld%^1.7)*TransTime. Where:
Syld% = sediment yield to stream, %.
TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.
Ex: Vege buffer 85% effective, 3 year erosion contrl plan. Rcvry = 15 yr.

Recall that the CWA S 404 exemption for permanent and temporary roads and trails (including skid trails) is based on the application of mandatory best management practices -- two of which include establishing buffers and erosion crontrol:

- all permanent and temporary roads shall be located sufficiently far from streams or other water bodies (except for crossing) to minimize discharges;

- fills shall be properly stabilized and maintained during and following construction to prevent erosion; ....

Both tables "Road Erosion Recovery, Years" and "Road Erosion Material Yield to Stream, cub ft/road acre" relate to the effectiveness of buffers at preventing stream sedimentation and the effectiveness of erosion control in reducing the amount of material headed for the stream. Both tables are based on a value of 0.3 cubic foot of stream sediment per road acre produced from properly installed BMP's (85 89 139 141 142).

The "Road Erosion Recovery, Years" table shows the trade-off between road location to maximize buffers or the need for erosion control where buffers are less effective. Table also indicates the long term effects of "temporary" roads that are allowed to deteriorate.

Road Erosion Material Yield to Stream, cub ft/road acre*

Sedmnt Yld%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	0.4	0.4	0.4	0.7	0.7	0.7	1.0	1.1	1.1	1.1	1.8
2	1.8	2.6	3.7	4.6	5.8	6.6	7.7	8.5	9.6	10.7	15.4
5	9.6	15.2	21	27	33	38	44	50	56	62	91
10	32	50	70	89	109	129	149	168	188	208	306
15	63	101	140	179	219	258	298	338	377	416	615
20	103	165	229	293	358	422	487	552	617	682	1006
25	150	241	335	429	523	618	713	808	902	997	1471
33	241	387	537	688	840	992	1144	1296	1448	1600	2361
50	489	785	1090	1397	1704	2013	2321	2629	2938	3246	4790
67	804	1292	1793	2298	2804	3311	3819	4326	4834	5342	7882
85	1205	1936	2688	3445	4203	4963	5723	6484	7246	8006	11814
90	1328	2134	2963	3797	4632	5470	6308	7146	7985	8824	13020
95	1457	2340	3248	4162	5079	5997	6916	7835	8754	9674	14274
99	1562	2510	3484	4464	5448	6432	7418	8404	9390	10376	15311

* Cumulative sum of annual road erosion material yielded to a stream starting from initial disturbance and ending with yields less than 0.3 cuft/road ac:
Tot Road mtrl, cf/a = SUM [0.4Syld%^1.7 * e^-(yr/TransTime)] Where:
Syld% = sediment yield to stream, %; f(buffers & expedient traps).
TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.
Ex: Vege buffer 85% effective, 3 year erosion contrl plan, 1024' drain x 45' exposed width. Road mtrl, total cf = (1024x45/43560) x 140 = 148 cf
Same road, 10 yr stability (no erosion plan): (1.06) x 416 = 441 tot cf
Same road, 33% buffer, 10 yr stablty: (1.06) x 5342 cf/a = 5663 tot cf

The longer it takes to establish stream protection by either providing buffers or erosion control creates a certain volume of sediment in the stream. The table "Road Erosion Material Yield to stream, cub ft/road acre" is a conversion of the time it takes to establish effective erosion control and the influence of different buffer conditions into stream sediment. Entirely too many site visits that displayed massive sedimentation from roads and land use activities were passed off as "no big deal"; it is a big deal and the table provides numbers of just how big it can be.

The values can be used in 3 basic ways; first, to test various locations versus costs for erosion control; second, to identify likely long term effects for stream restoration costs; and, third, to see if the conditions for CWA S 404 exemption are likely to be met.

>>>> T* Rcvry, yr = use best guess on temp recovery; no data.

Current field experience suggests that not many Rocky Mountain streams have temperature increase problems. However, this perspective may change with better efforts to locate field problems.

>>>> O* Rcvry, yr = 1 year recovery after BOD source control; no data

Current field experience suggests that not many Rocky Mountain streams have oxygenation problems. However, this perspective may change with better efforts to locate field problems.

>>>> M* Rcvry, yr = 20 year ion release after source control; no data

Acidic, metal-laden discharges from old mines is one of the most difficult pollution control problems nationally. In Colorado, an estimated 10,000 old mines has generated 1,300 miles of damaged or barren streams (143). Control is difficult because of the high cost, rugged terrain, poor access, winter freeze up, high spring flows, and low late season flow conditions.

Acid drainage tends to be a self perpetuating cycle. For example, at pH's less than 3, soluble ferric iron (+3) oxidizes iron sulfides (pyrite) to release sulfuric acid and ferrous iron (+2); which is then re-oxidized to ferric iron (+3), and so on. This chemical reaction can be accelerated more than 10 times by the addition of the microorganisms. The bacterium Thiobacillus ferroxidans gets its metabolic energy from the oxidation of ferrous iron to ferric iron which creates the low pH and continues the self-perpetuating cycle. Any other metals found in combination with the iron or in a sulfide ore will also be released.

The treatments most likely to be of value in remote sites will be passive mine drainage treatment. The objective is to enhance natural processes that raise pH and remove metal ions. Project action will probably include a mixture of neutralization, aeration, dilution, adsorption, chemical precipitation, and biological extraction such as in the use of artificial bogs.

>>>> P* Rcvry, yr = 1 year recovery after source control; no data

Current field experience suggests that not many Rocky Mountain streams have poisoning problems. However, this perspective may change with better efforts to locate field problems.

>>>> E* Rcvry, yr = Q & Sed shifts are long term; use WRENSS

Stream channels are a integrated feature of the land; changes in the natural streamflow regime and sediment supply can result in channel instability and less capacity to safely pass periodic high flows. Accelerated bank erosion and flooding causes facility and property damage as well as impairs physical, chemical, and biological integrity of the water. These are 'significant impacts' in the context of NEPA.

In addition, National Forests are managed under legislation which includes securing 'favorable conditions of water flows'. Changes in this 'favorable condition' is by definition 'significant' because it relates to the enabling legislation of the Forest Service itself (99).

Geomorphic equilibrium is the idea that material, process, and geometry form a self-correcting balance. A watershed in equilibrium achieves a time-independent steady state that just transmits the runoff and debris characteristically produced under the controlling climatic regime. Stream water and sediment discharge, with associated channel material, slope, width, depth, and cross-sectional area characteristics, are clearly interrelated with basin size, shape, relief, and stream order.

If protective vegetation is removed, the surface shows a sharp increase in both runoff intensity and erosion susceptibility. The watershed responds with increased drainage density, increased channel gradients, and decreased local relief. Areas with new rill and gully development cross a response threshold, or discontinuity, which leads to a much drier soil water economy.

In summary, disruption of natural regime has long term consequences including channel aggradation or degradation, extensive bank erosion, new meander patterns, wide shallow cross sections, loss of pool area, vegetation encroachment, or reduced flood flow capacity.

>>>> **D* Rcvry**, yr = 1 year recovery after source control; no data

Current field experience suggests that not many Rocky Mountain streams have dissolved salts or nutrient problems that are not of geologic origin. However, this perspective may change with better efforts to locate field problems.

>>>>   Expected CWA Restoration Costs -- Physical Restoration Costs $1000

Be clear about these stream restoration costs. They reflect needless damage caused by poor choices or poor administration for which there is both responsibility and liability. T-Walk develops these costs as a measure of the legal liability to restore the stream; as such, they are approximations of current or projected conditions and serve only to flag liability. These costs do not include land treatment or naturally caused stream damage for which there is no liability under the Clean Water Act. (The actual land and stream treatments, schedules, and costs are to be detailed in the Remedial Action Plan.)

The Clean Water Act can be used to justify projects that re-establish stream health and the associated fisheries, but it is not a "fisheries improvement act" that supports upgrading a naturally deficient fisheries. Projects that upgrade fisheries benefits need to be justified and built on that basis.

>>>>   Sediment related restoration - the problem with sand is the major loss of aquatic insect production & loss of pool depth for overwintering fish. Actual sand removal -- compared to in-channel redistribution using structures -- seems to be the most cost effective and risk free intrusion into the natural system.

How much restoration is necessary now becomes a function of the Thalweg Standard and the recovery goal of both pool depth and Tarzwell Substrate Ratio. The basic T-Walk recommendation is to remove the sand from the stream rather than build structures for pools or to flush the substrates. The first point is to correct the problem rather than move it downstream. The second point is that stream structures often interfere with bankfull stream flow dynamics and create induced sediment deposition and additional bank erosion (99 144).

>>>>   "**S*SWEEP**" Costs = sand cleaning by area to T-std productivity.
>>>>   **S*SWEEP $** = ImpactArea, sf x sweeper$. Where:
ImpactArea = stream area of bankfull width x impact length, sqft.
sweeper $ = suction drdg, 25hp, ATV, <10' lift $0.12/sqft
>>>>   "**S*SCOOP**" Costs = volume related; sand removal from sites <5' deep.
>>>>   **S*SCOOP $** = Cubic Yard x scooper $ Where:
Cubic Yard = volume of deposits to be lifted.
scooper $ = basin, backhoe, haul - $8-10/cy
= backwater, backhoe, haul $5-8/cy
= suction drdg, 60hp, roadside, <30' lift - $8-10/cy
= suction drdg, 25hp, ATV, <20' lift - $15/cy
= suction drdg, 8hp, hand, >20' lift - $60/cy
Ex: Stream Bcs1Tc, 21'x3000' impact; **S*SWEEP $** = (63,000 x $0.12 = $7560.
Ex: Stream Abs15Rb, 100 cubyd spill in 7 pools. **S*SCOOP $** = $6000.

The S*Sweep cost is controlled by Tarzwell Substrate Ratio recovery and is related to the riffle and run habitat area that requires sand removal. The costs are typical for using a suction dredge to recover the damaged site (41 44 45).

The S*Scoop cost is controlled by the recovery of pool depths to match Thalweg Standards and provide for overwintering adult fish. Typically, backhoes, front end loaders, or ATV mounted suction dredges can be used. Also, try to find a use for the extra material; this avoids the expense of re-seeding the dump site.

Make the most of the stream power available. For example, streams will move excess sand through a steep reach; so if a sediment spill happens there, consider going downstream to where access is better, build an instream sediment trap, and periodically clean it out. For smaller spills, consider putting in a temporary sand bag dam and flushing sediments into the trap for easier removal. The point is to maximize the project benefit by carefully selecting restoration sites and working with the stream power.

For streams that could be impacted by a new project, consider building instream traps to prevent a downstream spread of sediments in case something does break loose. For example, if 100 cubic yards of excess material is expected, then one option is to dig a trench in the bottom of the stream to keep sediments within the sacrifice area (145 146). If the work is done during road construction, the excavated material becomes part of the road and any extra costs would be minor. Best of all, the Thalweg-Standard is met.

>>>> Predicting stream clean-up costs from road erosion depends on stream character and Road Erosion Material Yield to the stream (**REMY** - see Table).

>>>> Use the larger of either **S*SWEEP $** or **S*SCOOP $** for clean up:

Road S*SWEEP $ = RoadAc x REMY x (152/T-std TSR) x sweeper $
Road S*SCOOP $ = RoadAc x REMY/27 x scooper $

Ex: $202 clean up for 44x1200' road, 20% sedmnt yield, 4yr erosion control plan. T-std TSR is 32; clean up w/ 25hp suction dredge.

Road S*SWEEP $ = 1.21 road ac x 293 x (152/32) x 0.12 = $202
Road S*SCOOP $ = 1.21 " " x 293/27 x 15 = $197

The heart of the matter is that a basic, though unstated, land use policy of federal, state, and local officials is that road erosion control is an unnecessary expense. Therefore, it is not surprising that erosion control efforts tend to be minimal or not enforced within contracts, that they are consistently identified as a major cause of stream deterioration, that they are specifically emphasized in the legislative history, and that they are often at the center of litigation and cumulative effects debates.

The T-Walk perspective is that while road erosion control is perhaps a management prerogative, Robust Stream Health is not. The purpose here is to balance out both sides of the erosion control versus stream recovery issue. Of the 4 factors used by T-Walk, 3 relate to management choices: the capacity of the buffer and expedient traps, the time it takes to establish erosion control, and the amount of road prism contributing sediments. These factors are summarized in the "Road Erosion Material Yield to Stream" table as "Sediment Yield %" and "Transition Time to Effective Erosion Control". The tabular values are totals of annual amounts of erosion that exceed 0.3 cubic foot per road acre. The 0.3 cubic foot limit is a researched value achieved using normal Best Management Practices on timber sale main haul roads in Deadhorse Creek, Fraser Experimental Forest near Fraser, Colorado (141 142).

The 4th T-Walk factor uses Tarzwell Substrate Ratio as an index of how much stream bottom has to be cleaned per cubic foot of sediment delivered. For example, a cubic foot of sand will damage about 16 square feet of fine gravels (TSR=9), but only 3 square feet of large cobble (TSR=50).

Both S*Sweep and S*Scoop costs are calculated; the larger of these costs can then be compared for alternatives with different road location, road drainage, or erosion control plans. Current field experience suggests that the vote should go in favor of erosion control; it is about 20 times more expensive to take material out of stream than to keep it on-site.

>>>> <u>Expected CWA Restoration Costs</u> - Chemical Restoration Costs $1000
>>>> Cost data for restoration has not been worked up; go w/ your best guess.

No question about the importance of this subject. Nor does there seem to be any answers short of detailed studies and full understanding of the complexity that spans politics and economics as well as environmental science. Current field experience suggests that restoration projects will be difficult, expensive, lengthy, and potentially full of litigation.

In the advance warning context, T-Walk can be used to flag developing situations and help narrow the list of sample sites needed for chemical analysis. However, hazardous materials is well beyond T-Walk; for you to be safe and still respond properly follow the emergency response prodcedures set up by the State and EPA.

>>>> <u>Reviewer & date passed to authority</u> - water quality is the manager's responsibility; your job is to pass along the right information.
>>>> ==
>>>> Reviewer & date passed to authority:

>>>> ==

While management is ultimately responsible for clean water, the advice is only as good as the technician's commitment to a good job. The signature is a part of the feed back loop that has to be fast, friendly, and formal.

>>>> <u>Remedial plan</u> - defines the watershed treatment plan and implementation schedule. Identify remedial **Objectives** and the completion target date necessary to prevent more damage.

The remedial action plan is intended to be simple and to get control of problems and situations before they get a head start. The technician identifies the plan objective, who benefits, values to be protected, a list of work items, costs, and people or skills needed. When restoration problems are beyond this level of planning, then take whatever simple action is needed to reduce the damage and note the need under 'Monitoring follow-up' for restoration planning.

Begin the land treatment phase early to reduce the sediment supply. Begin with the upper watershed and correct problems on the way down. Make a multi-year plan with elements designed to make full use of natural processes. This will save time as well as reduce costs. Identify plan elements for what can happen concurrently; for example, instream construction and planting brush species for bank stability can be done concurrently with land treatment.

However, postpone any instream construction that will be adversely affected by high flow or high sediment loads until the upper watershed is in good hydrologic shape. Great care is necessary with structures: without proper siting, an instream structure often fails design criteria; creates bank erosion problems; increases stream widening; or requires high maintenance (144).

Natural processes are the most successful; design the restoration features to mimic natural systems. Apply this rule generally, and with particular vigor when designing instream structures. Consider holes, sumps, or an instream sand splitter for periodic sediment removal (147). But try to favor temporary measures that help re-establish natural control.

The restoration cost estimates also need to include clean-up. Please remove all temporary devices or structures, clean up debris, and pull out any re-bar stakes as a safety precaution. If possible, return the site to a natural appearance and re-seed the disturbed sites. Make it look like someone cares.

>>>> Identify specific **Sponsors/clientele** currently affected by the situation and the **values to be protected**. Identify any special or targeted plant or animal species.

Getting the job done requires a sound technical plan -- and the negotiation of conflicts generated by the plan. The need for restoration implies something is wrong and that existing resource use has to change; this affects people's perception of their rights and economics, both of which are highly emotional.

All projects of any significance re-distribute welfare from group to group, time to time, and place to place. Social conflict among the different groups is almost always present, and can spell success or failure for the management effort. The identification of sponsors and clientele and associated values helps focus on the problem, the solution, and the conflict.

In large part, the issues involved are economic. Restoration is concerned with improving long term economics by recovery of resource vitality. The tendency to have only limited short term incentives makes building local support for

restoration difficult. However, sometimes clientele are more willing to forego some current use if they have a share in the future, or can be shown that continued levels of resource use will result in loss of future options anyway.

This is a reminder that the values to be looked at span the broad range of watershed responsibilities including special plant or animal species. The following guidelines also provide a context for possible local support beyond the watershed boundary:

- The value to this and adjacent property from continued on- and off-site erosion damage, including impacts on developed areas, reservoirs, water rights, delivery systems, irrigation, recreation, and other water uses.
- The value from the standpoint of flood damage reduction.
- The value from the broader viewpoint of Nation-wide conservation. As areas are damaged, resources have to be used for restoration and the burden of taxation and production on the remaining area becomes increasingly greater.
- The value of litigation as it influences the job of land stewardship.

>>>> **Work items** - show what & how much has to be done; use the abbreviated list for common channel, road, revegetation, and expedient (temporary) sediment or erosion control measures. Figure necessary costs & special skills. Then add name and telephone of the planner for later questions.

>>>> Some Regional unit costs - to be applied with care!

		$ low -	high
Clow	Low flow channel structures for sediment contrl, ea	1100	3600
Cnew	Channel construction new/enlarge, cubic yard	15ave	
Crem	Channel debris/sediment removal, $50/lrg woody debris	10/cy ave	
Cstb	Channel/shore bank material stability, cy riprap	10	25 w/revege
Ebsn	Expedient sediment/debris basin, cy	10 ave	
Ecut	Expedient in-channel trap (trench or trough); no dam	10/cy ave	
Edam	Expedient siphon dam (slant or 'T' pipe), dam	700/<10' high	
Ediv	Expedient storm runoff diversion, linft	100 ave	
Efil	Expedient filter/sorbent material fence, linft	10 ave	
Efur	Expedient log & furrow erosion barriers, cy	12	17
Epit	Expedient small sediment catch 'pit', cy	0	10
Erow	Expedient slash/brush windrow, linft	0	3
Rbar	Water bar, roll dip, & other cross drain repair, ea	25	
Rcul	Bridge & culvert stabilization, ea	500	
Rdrn	Road, trail, & corridor drain ditch stabilztn, linft	0.5	
Rstb	Road fill & bank stability, sqft	1	
Vbfr	Permanent vegetation buffer for sedmnt cntrl, linft	0	0.2
Vcvr	Vege cover density for on-site erosion cntrl, sqft	.1	1
Vexc	Vege protect by livestock exclusion, mi	elect= 500,	barb= 3000

This partial list of work items can be expanded by you as you need to. Keep track of the design specs and add them to a notebook. Build project costs in detail so project actions can be more easily matched to field costs.

These costs will be updated as information becomes available. Right now, not much is known that is effective for project planning. It may be that the problems and limiting factors are sufficiently complex so that any cost estimate is little more than a guess. Live with it; don't hesitate to use your best estimates regardless of how they compare to these unit costs.

>>>> Monitoring - review the need for extra monitoring or intensive field surveys. Direct monitoring efforts to results that are of evidentiary quality & can be used to assess - or restore - CWA Robust stream health.

Back to the beginning. The existing need for top quality monitoring is further accentuated by the latest changes to the Clean Water Act. In particular, Sec 319 requires the evaluation of non-point source pollution control activities in the context of State run programs and existing case law is strong enough to require restoration. In terms of monitoring, these are still key objectives:

- Stay off the State's impaired watershed list.
- Fix watersheds that are currently on the list.
- Fix unlisted watersheds that fail to meet Clean Water Act goals.
- Satisfy mandatory BMP's and criteria for CWA S 404 exemptions.
- Make monitoring efforts good enough for judicial use under Sec 505.
- Report results in terms of Stream Health.
- Commit people to stay on top of high risk activities.
- Concentrate on eliminating personal levels of liability.

Be aware that good monitoring plans are needed for budgeting and project control; that broad generic statements are useless when the issues are factual; and that the burden of demonstrating compliance is on the agency (27).

If you have to develop a monitoring plan, at least start with the following questions as a checklist to help focus on the data and analysis needed to meet statistical, mathematical, and procedural validity:

- Have data collection methods been standardized and applied consistently?
- Have analytical methods been standardized and applied consistently?
- What type of data and accuracy is required?
- What time and space is represented?
- What frequency and distribution is represented?
- What is the physical, chemical, or electrical basis of the equipment?
- Does equipment measure what is required?
- Does it have the required accuracy under field conditions?
- How many units of equipment are required?
- Are maintenance and calibration provided for?
- How and when will data be collected?
- How will data be recorded and stored?
- What is the introduced error?
- Is the analysis statistically, mathematically, and procedurally valid?
- Is interpretation logically correct and appropriate to the objective?
- Are the people involved with equipment and collection competent?
- Are the people involved with analysis and interpretation competent?

>>>> Specify where to sample, who is to do it, which methods, parameters to measure, and frequency. Location is critical; look for sites that are 'weak link' sensitive to early stress or that are expensive to fix:

- Bank Comptncy: raw>grs>brs=trs; s>f>>g>>c>b>r; M >>L=J >G >T >R include ad-water, de-water, spill sites, peak & duration changes.
- 1/8 mi (660') downstream of road crossing: culverts > bridges.
- roads that concentrate runoff: design >> temporary > primitive.

The focus is that "Maintenance of ecological integrity requires that any ... physical, chemical or biological change ... be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original." Then use the following checklist for defining the when, where, how, what, who, and why:

- Concentration or dispersal of pollutants thru physical processes.
- Concentration or dispersal of pollutants thru chemical & processes.
- Concentration or dispersal of pollutants thru biological systems.
- Effects on key species.
- Effects on natural temperature patterns.
- Effects on dissolved oxygen conditions (food, propagation, cover).
- Effects on natural stream reaches, flows, and circulation patterns.
- Effects of road construction and maintenance on stream systems.
- Effects on aquatic ecosystem stability & diversity.
- Effects on aquatic ecosystem productivity.
- Rates of inorganic sediment accumulation.
- Rates of eutrophication and organic accumulation rates.
- Rates of stream health restoration and recovery.

Monitoring doesn't <u>have</u> to be complicated; think through how the data is to be used and avoid making it more complex than necessary. Monitoring at weak-links in time, space, and administration (or expensive-to-fix areas) is cost effective because it focuses attention on when an impact is expected, where it is likely to show up first, what administration is needed, and who carries the big stick.

NOTES

1 Ohlander 1994a. Part 1, pg 1-2, Table 1.1 and footnote 53.
CWA S 404(f)(1)(E) defines protection requirements for roads using the standard of "no impairment" to chemical and biological characteristics. Tests to show compliance or non-compliance are at 40 CFR 230.10(c).

2 Ohlander 1989. Part 5. To build an advanced warning system, the functions and effects in Table 1.2 (Part 1 Legal Framework) were reviewed to determine which field measures were most appropriate in reducing long term vulnerability for resource management. The list of "Required" elements in an advance warning system (and T-Walk) include:
- Concentration of pollutants through physical processes.
- Dispersal of pollutants through physical processes.
- Inorganic sediment accumulation.
- Natural stream stability (flow, circulation, and habitat).
- Aquatic ecosystem stability and diversity.
- Aquatic ecosystem productivity.
- Hydrologic cycle and storm runoff control.
- Stream health restoration and recovery rates.
- Comparison of actual condition to Reference conditions.

Items not included as part T-Walk include:
- Comparison of water chemistry to State water quality standards.
- Eutrophication and organic accumulation rates.
- Pollutant concentration and dispersal through biological systems.
- Pollutant concentration and dispersal through chemical systems.
- Effects on key species and natural temperature patterns.
- Effects on dissolved oxygen conditions (food, propagation, and cover).

3 Ohlander 1994b. manual

4 Odum 1971. p20.

5 DeRienzo 1989+.

6 U.S.EPA. 1973. Pursuant to CWA 304(f), this is official guidance. P79.

7 Ohlander 1992. Part 2 Watershed reporting.

8 Colorado Attorney General. 1986.

9 EPA 1989b Pg 14. EPA 1993 for Region 8's antidegradation program, p33. Data requirements establish a low threshold or definition of "significant degradation" and may be based on simple analysis of land use, pollutant sources, biological health, etc, to ensure that the least-degrading alternatives are being implemented (p57-58).

10 EPA. 1973 pg 55-59 refers to the 1973 FS timber sale contract that is still in use. Except at crossings, contract provision (B6.5c) prohibits wheeled and track-laying equipment use in streamcourses that have defined or scoured channels, that show evidence of developing sufficient head of water to move debris or erode the channel, or which may develop such characteristics if diverted or blocked by logging activities.

Because this was issued under CWA S304, these streamcourse protection definitions remain in effect until EPA modifies or rescinds them by publication in the federal register. But there is an interesting point: The actual definitions came from the 1968 Manual, FSM Title 2400 -- Timber Management, Sec 2456.5 "Protection of Streamcourses ..." for which the legal basis for streamcourse protection is the 1897 Organic Act's objective of "... securing favorable conditions of water flows...." rather than the 1972 Federal Water Pollution Control Act.

"Streamcourse" is now in the Timber Sale Administration Handbook with a slightly different definition: "Streamcourses are streams, draws, washes, depressions, or other features shown as streamcourses on the Sale Area Map." (FSH 2409.15.0 page 10/11 8/3/92). Streamcourses may be drawn

for whatever reason; however, they MUST include the reasons given in the 1973 guidance until EPA chooses to rescind or modify this 1973 guidance.

FSH 2409.15.61.41 "Streamcourse Protection (B/BT6.5)" further states that "Those streams and waterways not shown on the sale area map are not subject to the terms of this provision ...." and refers to B/BT6.422. At 61.32b "Landings and Skid Trails (B/BT6.422)" requires that the FS and the purchaser agree on the location of all landings, tractor roads, and skid trails prior to their construction.

FSH 2409.18, Chapter 30 & 40 discuss sale area design and requirements for field reconnaissance and area analysis. Comments from Jeff Starnes and Robert Wolfskill (R-2 Timber Management) suggest incorporation or blending of project area map detail with the timber sale logging plan detail with specified BMP's with particular attention to COE BMP #1.

11 Ohlander 1993d. CWA S304 authorizes EPA to issue official guidance; viewed by the court as a level of quality to be achieved, though not necessarily by the methods or processes chosen by EPA. A key point is that S304 guidance remains official until EPA formally modifies or rescinds, which they have not done for the 1973 silviculture material.

12 USFS, R2, 1993. Integrated Resource Inventory handbook addresses consistency in defining the Common Water Unit (7/93 draft). For some applications like timber sales, field validation is required (EPA 1973); this may be part of this step or left for project planning.

Watershed boundaries and the total drainage network is mapped on the 1:24,000 scale topographic map as part of the Common Water Unit. Since the USGS maps do not mark all intermittent channels, the omitted channels will be identified using the "contour crenulation method". Questionable channels are verified with aerial photographs, or in the field.

The rules for contour crenulation are as follows:

1. Make a 1" X 2" mylar template with a 120 degree angle.
2. Locate existing USGS streams and extend the stream upslope through the bend in each contour showing less (sharper) than the 120 template.
3. If a channel meets rule #2 but is separated from the existing network by 1 or 2 contours greater than 120 degrees, connect the channel to the network. If separated by 3 or more, go to rule #4.
4. Check the aerial photo; if it shows the segment is actually part of the network, connect the channel. If not, go to rule #5.
5. If the disconnected channel is 2nd order or larger, or is at least 10 mm (800 feet), or contains a wetland, mark the channel "DC" (disconnected channel). Otherwise, erase the channel from the map.
6. On adjoining map neatlines, match the stream segments exactly.

13 EPA 1989b. S401 allows the state to certify that S404 permits will meet water quality standards; the state may impose additional requirements. The COE and State will often issue a joint statement regarding S401 Certification on S404 permit conditions. For example, the Joint Notice issued by U.S. Army Corps of Engineers and Wyoming Dept of Environmental Quality lists which of the NWP have been denied state S401 Certification.

14 EPA 1983b. Aquatic life health classes. Foreward, I-1, and V-4.

15 Activities of federal agencies are subject to CWA S 404 regulations including enforcement [(CWA S 404(s)(1) & (3)); S 404(n); (S 309(a)(1) & (c)); (33 CFR 323.3(b)); 33 CFR 326].

16 Carey 1994. Personal communication.

17 Minimum level designated (beneficial) uses are deemed attainable if they can be achieved under existing conditions by imposition of effluent control and best management practices (40 CFR 131.10(d)). As an antidegradation issue, improvement in diversity, ecosystem stability, or productivity raises the bottom level against which compliance to

antidegradation is then measured. The State is obligated to achieving the highest statutory and regulatory requirements (40 CFR 131.12(a)(2).

18 Ohlander 1994a. Part 1 page 16.

19 CWA S402(p) Municipal and Industrial Stormwater Discharges is part of the Nationwide Pollutant Discharge Elimination System (NPDES) (40 CFR 122). EPA 1992a is a detailed manual for construction related storm water control, pollution prevention plans, and best management practices.

20 USFS 1980. "Water Resources Evaluation of Non-point Silvicultural Sources" (WRENSS) is official guidance issued in agreement with EPA by agreement of Max Petersen, Chief, USFS (EPA 1985 pB-37).

21 USFS 1994. Wyoming Storm Water Permit program.

22 EPA 1992a & b. Storm water management planning for industrial and construction activities are detailed and list some BMP's. Wyoming requires a pollution prevention plan patterned after that used by EPA. Meetings with Wyoming resulted in the development of a "Special Project Specification" to be used on road contracts and a simplified plan format.

23 EPA 1985. Task force on nonpoint source pollution. pg 25. Also FN 20.

24 Wolfskill, 1994. Sale Area Maps are frequently drawn at 1:15840 (4"/mile), but not less than 1:31680 (2"/mile).

25 U.S. FS. 1973. The FS Timber Sale Contract has provisions to protect streamcourses including this prohibition of wheeled or track-laying equipment. Other provisions include field mapping of all streamcourses to be protected before the contract is awared (B1.1(o)); agreement by the FS on the location of all landings, tractor roads, and skid trails prior to construction (B6.422); and erosion prevention and control (B6.6).

26 EPA 1973. "All streamcourses within a proposed timber sale area shall be classified during the field examination ...." p56.

27 EPA 1985. Nonpoint source pollution control strategies. Signed by Max Petersen, Chief; the USFS agreed to monitor baseline water quality and NFS operations to determine effectiveness of prescribed best management practices (p25 and B-37). See Ohlander 1993b for an analysis of requirements for baseline water quality.

28 SCS. 1986. Urban hydrology p 2-9 to 2-11 uses "Connected Impervious Area" as a summary of areas with extensive pavement, roofs, and concrete gutters that connect with storm sewers and stream systems. The analysis is based on Runoff Curve Numbers and provides a measure of urban watershed response to storm events.

29 Determination of Aquatic Ecosystem Cumulative Effects (40 CFR 230.11(g)) is part of CWA S404(b)(1) guidelines.

30 USFS 1994. R-2 travel classification.

31 Gray and Leiser 1982. Good technical material on slope stability.

32 Troendle 1983. Clear cut 36% of a 101 acre subalpine watershed with soils derived from alluvium, glacial outwash, sandstones, gneiss, and schist. Data for 1984 - 1991 supplied by Jim Nankervis, Rky Mtn Station.

Campbell and Stednick 1983. Data from Deadhorse Creek on sediment flow distances was compared to those calculated by the Vbfr equation. Vbfr underestimated 2 (of 9) buffers by 10% and 20%. Since the treatment in Deadhorse watershed was somewhat extreme -- 36% clear cut in a subalpine climate resulting in a sediment yield of only 0.3 cf/rd ac/yr -- suggests that the vegetative buffer equation, Vbfr, provides an excellent estimate of buffer distances needed for stream protection in similar geologies.

33 US COE 1991. NWP #14 Road Crossings, page 1.

34 Carey 1993 personal communication. COE Omaha District policy.

35 Cassells 1993 personal communication. R2 uses a 50 year design for most small and medium road crossings. In snow dominated hydrologic

regimes, the 100 year peak is about 10% greater than the 50 year peak; in rain dominated hydrologic regimes the 100 year peak is more than 50% greater than the 50 year peak.

Cursory look at (100 yr)/(50 yr) flood peak ratio for some streams in Colorado: Bear Creek at Morrison (1.5), Michigan Creek above Jefferson (1.05), Cottonwood Creek near Buena Vista (1.12), Middle Boulder near Nederland (1.06), Tarryall Creek near Como (1.12), Clear Creek above Clear Creek Reservoir (1.08), Michigan River near Cameron (1.08), and Cherry Creek near Franktown (1.5).

36 EPA 1992a. Chapter 2 "Storm Water Pollution Prevention Plan" provides a step-by-step explanation of how to develop and implement the plan.

37 USFS 1980 WRENSS Chap V, pages 4, 27, 29, 33, 35. Barfield 1983 pg 18.

38 USFS 1980 WRENSS channel gradient changes pII.14, II.28, IV69. US Bur Rec 1977; downstream channel effects pg 789-795. Barfield 1983, pages 160-161 and 199+. Also SCS 1977 open channel design.

39 EPA 1992b. Control of industrial storm water pollution.

40 Chavez 1986+.

41 Decker 1986+.

42 Bevenger 1986+.

43 Chambers 1986+.

44 Sullivan 1988.

45 Marsh. 1992. On suction dredge operations on steep streams.

46 Wohlwend 1989. Gary Wohlwend, the "Montana Stubby", cut a 3' long 4" diameter plastic pipe, glued on a clear plastic bottom, added handles, and called it a "snooper". In so doing, he built a simple solution to the difficult task of seeing a stream bottom without getting your face wet. There are many ways to do this including a plastic mailing tube, a plastic baggie, and some rubber bands.

47 Ohlander 1991. Photographic evidence - FIELDSCRIPT rules.

48 Pfankuch 1975.

49 In situations with large sediment spills, the volume of material to be removed can often be estimated from an elevation survey of a grid or set of cross sections. At each point on the grid, the rod is first set on the surface of the deposit and read, then pushed through the deposit down to the original surface and read again. In this way, the volume of the spill can be calculated from the difference measured at each point.

50 EPA 1983 b&c; mainly the manual for Waterbody Surveys & Assessments. See Pg V-4. (EPA names were changed to Robust, Adequate, Diminished, Impaired, Precarious, and Catastrophic). These definitions are official (S304) and retain a strong logic and biologic rationale that does not, at the same time, incorporate the metrics that might be used to measure them. Such definitions could be used by Ernst Haeckel, who first coined the word "ecology" in 1869.

51 Schwarz, et al. 1976. Ecological stability. Wildld Pln Glossary, p65.

52 Schwarz, et al. 1976. Ecological carrying capacity, Ford-Robertson p40.

53 Meehan, W.R., ed. 1991. Pages 200, 511, 516.

54 Meehan, W.R., ed. 1991. Pages noted. Woody debris includes twigs, branches, logs, boles, treeroots, rootwads; large woody debris (lwd) => 10cm diam (4")(p18). Lwd decay is slow; high C:N > 1000:1; nitrogen fix bacteria accounts for much usable stream nitrogen (p28, 30) with decay of branches & twigs making up much of the annual input (p27). Often reported in terms of density per unit area (#/area) or volume per unit area (cubic meter/square meter) of stream; for debris features as windrows, piles, jams, logs, boles, or dams (p167).

55 Meehan, W.R., ed. 1991. Pages 169, 170, 196.

56 Meehan, W.R., ed. 1991. Pages 20, 163, 552.

57 Meehan, W.R., ed. 1991. Pages 117, 489, 504, 510.

58 Meehan, W.R., ed. 1991. Pages 169-70, 199, 490-91, 505, 507.

59 Meehan, W.R., ed. 1991. Pages 121, 202, 473, 547. Stability can be determined from the relationship of lwd length and diameter compared to channel width (Fig 5.17 p168).

60 Schmal, 1992.

61 USFS 1980. Water quality monitoring.

62 MacDonald, Smart, & Wissmar. 1991.

63 EPA. 1973. Pursuant to CWA 304(f), this publication on the control of silviculture related pollution was acknowledged by EPA Administrator Russell E. Train as official guidelines for, among others, the S.208 program. It is important to understand that THESE guidelines REMAIN official until EPA either rescinds or updates them according to the requirements in S304(f). The guidelines were reviewed (Ohlander, 1993) to determine compliance and to redflag monitoring requirements.

64 Chow. 1964. Page 21-11.

65 The National Forest Management Act includes the mandate that land productivity shall not be impaired and that destructive activities will be either modified or discontinued. NFMA does not specifically define impairment or how it is to be measured; the legislative history states that 1) it is carried from the 1960 Multiple-Use Sustained-Yield Act (MUSYA), and 2) that "nutrient degradation" is a matter of real concern. MUSYA does not define impairment, nor mention soil fertility, but it does refer to the "prevention of soil erosion" clause in the 1944 Sustained Yield Forest Management Act (16 USC 583).

NFMA quote: "The Committee intends that an overall program of on-the-ground monitoring, coupled with research, insure the sound management of National Forest System lands. .... If research or evaluation establishes that a management system or method is producing impairment of the productivity of the land, such system or method will be modified or discontinued."

"The subject of "nutrient degradation" on forest soils is a matter of real concern. Additional research and more comprehensive monitoring and evaluation of nutrient degradation is a high priority example of the benefits expected from sound application of the research and evaluation provision of the Committee bill." [76 USCC&AN 6699].

The Federal Land Policy and Management Act mandates, among other things, that allotment management plans (AMP) will be written to meet multiple use, sustained yield, economic, rehabilitation, protection, and improvement objectives. FLPMA 43 CFR 1701-1782 added this criteria and associated time frames.

Freeouf (1985) provides a short summary of about 30 laws and executive orders that require the protection of site quality.

66 Lennahan 1993. Comments on land productivity issues.

67 Maxwell and Solomon 1980.

68 Chow. 1964. Several references to Runoff Curve Numbers. Pages 21-10 -32; 22-47 -51. Ohlander. 1992. Part 2, pages 2-12 to 21.

69 Chow. 1964. Pages 22-47 -51. Ohlander 1992. Part 2, page 2-13. In many forest types, humus depth increases with stand age until an equilibrium is reached. Depths of 12" are not uncommon, but 6" is about average for old and protected forest sites. Forests on unstable soils or those with a history of relatively frequent fires develop much less than 6" of humus with, perhaps, 3" being a realistic goal for long term forestry.

Under dry climatic conditions, humus layers tend to be shallow in forest-range types. Soil group, cover type, land use, and cover density (including litter) are the controlling variables for infiltration.

70 USFS 1966. p33, 49, 53-59. Ground cover surveys of the 1930s, 40s, & 1950s are summarized as graphs of "infiltration v. ground cover"; "overland flow v. ground cover"; and "soil losses v. ground cover"; ground cover includes plant, litter, twigs, etc, but no rock.

71 USFS 1966. p123 on hydrologic recovery.

72 Flinn 1974.

73 Burroughs & King 1989.

74 Reid & Dunne. 1984.

75 USFS 1981. R1/R4 sediment guides

76 Chavez et al 1993. The Pikes Peak highway is 77 years old, built in very erosive coarse granites, and used for, among other things, recreation racing. Along a 12.5 mile stretch, 837 THOUSAND cubic yards of gravel has been added over the last 20 years to replace gravels lost to erosion and sidecasting during snow removal and surface maintenance. Accurate records for 1989-1993 show gravel additions of 421 cy per road acre per year (p13). The gravels lack a binder and are easily moved.

77 Ohlander 1987b. Road erosion buffers.

78 Ohlander 1993a. The buffer study was updated and expanded to include geologies common to the Black Hills and different buffer configurations like swales or eroded surfaces where the 100′ per 1′ gully is not right.

Samples from the Black Hills, South Dakota, included 44 road sections in schist, limestone, quartz mozonite, and sandstone parent material. The equation appeared adequate for all geologies except the "red beds".

79 Harvey, etal, 1985. Fig 4-16, p79 defines geomorphic thresholds using Stream Power (plotted as lines of relative Stream Power). The zone between SP = 1 and SP = 2 (with SP =1.5 the most sensitive separation) identifies a transition from valleys with few gullies to those with numerous gullies. The equation for the lower threshold (SP = 1) is:

$Slope/Width = 0.35/Area^{0.55}$ (measured in kilometers).

This equation was modified for T-Walk so measurements in Slope %, Width in feet, and area in Acres could be used directly. Also the "0.55" exponent was changed to 0.5 to accommodate simple calculators:

For SP = 1, $Slope\%/Width' = 2.4/Acres^{0.5}$ and

For SP = 1.5 $Slope\%/Width' = 3.6/Acres^{0.5}$ where:

Slope% = clinometer read as %, i.e. 6% is 6.

Width′ = wetted perimeter at flood flow, feet.

Acres = drainage area of site, acres.

80 Ohlander 1987b, 1993a. Road erosion buffer studies in the Black Hills and Medicine Bow Mountains provide data on road erosion as rill depth, road slope, and distance between drains. These values were converted to Slp%/Wid ratios and area estimates for acres so they could be plotted in relationship to the threshold equation derived from Harvey (see FN 79).

81 Osborne and Kovacic. 1993. Vegetated buffer strips for N & P.

82 EPA, 1992a&b. Technical material relating to pollution prevention plans for construction activities to comply with the 1987 CWA S 402(p) regulations for Storm Water permits.

83 Buffer shapes and road conditions for 90 sites in the Medicine Bow Mtns were analyzed in 1976 (Ohlander 1976); in 1988; and in 1993 to improve the Vbfr equation as a simple field guide to protect water quality. The original data sampled paved (n=10), light duty surfaced single and double lane (n=56), and unimproved dirt roads (n=24) on forested lands. Subsequent efforts have been to validate the tool for other areas.

Campbell and Stednick (1983) studied sediment flow distances generated by simulated high intensity storms (> 10 year return frequency) on 9 sites on Deadhorse Watershed, Fraser Experimental Forest. This data confirms the application of Vbfr equation.

84 Sediment Delivery Index, calculated from a stiff diagram, incorprated scales for water available (linear), soil texture (% clay and silt), ground cover (log), slope shape (buffer shape in linear stages from concave to convex with straight being 1/2 way), slope gradient (linear), delivery distance (log), surface roughness (linear), and specific site factors like non-wettability, minerology, microrelief, and soil aggregates. WRENNS, p IV 54-56

85 Packer & Christensen. 1964. Table 2 (cross drain spacing) factors include road grade and soil. Table 3 (buffer width) factors include spacing and kind of obstructions; namely holes, logs, rocks, trees & stumps, slash & brush, and herbaceous vegetation with side slopes up to 80%.

86 Swift 1985. Swift 1986. Fig. 3 & 4 show major differences in buffers of "no litter" (prescribed burn), "no brush barrier", and "brush barrier" (windrow) with relatively minor correlation to slope (7 to 80%) as a single factor.

Some users suggest changes in buffer standards because construction methods have changed from the 1960s when the studies were done (p28).

87 Trimble and Sartz. 1957. Fig. 3 shows very little correlation between the sediment flow distances and buffer slope. All 36 measurements were from similar forest litter, humus, and mineral soil conditions. Culvert spacing was more or less based on (1000/(road grade %).

88 Barfield 1983. p 566 on sediment filters; grass density is a factor.

89 Kochenderfer, et al. nd & 1984. Minimum-standard forest truck roads designed to protect water quality.

90 Plafkin et al 1989.

91 Alexander and Hansen 1986.

92 Hynes 1970.

93 Karr & Schlosser. 1977.

94 Lloyd 1986.

95 Platts et al 1983. Pools p9

96 Whitton 1975.

97 Lisle 1987.

98 Factors in 40 CFR 230, Subparts C-F, considered relevant to minor discharges, include all the factors. The COE Nationwide Permits authorize limited stream impacts. For example, NWP #18 provides for minor discharges up to 25 cubic yards and impacts up to 1/10 acre of special aquatic site. Since pool and riffle complexes are special aquatic sites, the 4356 sq ft limit would be a 200' reach 22' wide.

99 Silvey 1983 to 1990.

100 Dunne & Leopold, 1978. Velocity estimate is described on page 655.

101 Heede 1974.

102 Tarzwell 1937.

103 Tarzwell 1938.

104 EPA 1971. p 2.1-16ff. This was during the time that water quality responsibilities were transferred from the Fed Wtr Pollution Cntrl Admin to EPA. FWPCA and EPA included Tarzwell Substrate Ratios in training courses until the National Training Center at Newtown, OH, was shut down in 1978 or 1979 (information from Don Klemm, EPA, Cincinnati, OH).

As late as 1983, Tarzwell Substrate Ratios were still used in training for Hazard Evaluation and Environmental Assessment (Course 165.6).

105 Platts et al 1983. Cobble embeddedness rates the degree that larger particles are surrounded or covered by fine sediments. As embeddedness % increases, the biotic productivity is thought to go down (pg 16). The observation (by category) is considered fairly dependable with "fair" accuracy; however, treating the category labels (1-5) as interval data for statistical purposes makes the analysis suspect. (Pg 56).

106 T-Walk training provides 2 basic skill levels: people with specialized knowledge of aquatic systems and people with only general knowledge. The specialists already have the field skills needed to implement T-Walk and field exercises with people from adjacent administrative units is about all that's needed to insure reasonable consistency. Training for people without specialized skills is structured more formally and includes field exercises with a trainer, practice on home streams, and a final review by a trainer to validate evaluations. The non-specialists training was started in 1992 and firm conclusions are not yet possible. Nor have the tests to check variation among trained observers on the same stream reaches been completed. But hang in there, we're getting closer.

107 CWA S 404(f)(1)(E) limits road and trail impacts to no impairment of chemical and biological characteristics. Given the difficulty of measurement 10%± seems reasonable.

108 Dunne & Leopold 1978.

109 Rosgen 1985.

110 Meehan, W.R., ed. 1991. Pages 163, 198-99, 416, 490.

111 Wolman 1954. The Wolman Pebble Count is normally used to construct a plot of cumulative frequency percentage versus the selected size. If bars or riffles are sampled, several geomorphic and channel stability predictions are possible from the comparison of study sites to reference sites. The standard of 100 samples provides a standard deviation of 12%; however, if the d84 is the size of concern, increase the number of counts to 200 or restrict the sample area to a particular sensitive feature should improve the statistical quality.

112 Bevenger 1993. Watersheds of concern were identified during development of an EIS. Field work included finding reference (no impact) conditions to match similar reaches in suspect watersheds. Along with other data, pebble counts were taken using a zig-zag pattern in an 1/8 mile reach.

The sediment related watershed cumulative effects is based on the idea that particle size distributions for unimpacted stream reaches can be used as basis for determining if study reaches are impacted. After statistical verification (Bevenger and King 1994, draft) monitoring for stream health and watershed cumulative effects begins in 1994.

113 Bevenger and King 1994. pebble count statistics.

114 SCS TR 25, chapter 6: channel stability.

115 Fortier & Scobey p955. Note Barfield p162 is misprint for fine sand.

116 EPA. 1986. toxicity.

117 Nunnally 1978.

118 Tanner 1968.

119 Barfield p198.

120 Mainly the idea and perspective from Luna Leopold. Luna served as an expert witness and technical consultant to the Forest Service during the instream flow water rights adjudication in Colorado Water Division 1. In the context of channel stability, his suggestion was to sample riffle or central bars using the Wolman pebble count method and use the d84 (diam = or < 84% of the pebbles measured) as a measure of the stream's structural resistance to high flow.

121 Gary Kappesser, Idaho Panhandle National Forests, uses "Riffle Stabilty Index" constructed from pebble counts and bedload transport.

122 USFS 1980. WRENSS

123 Theurer & Harrington.

124 EPA 1983b. Section on reference reaches.

125 EPA 1990.

126 On the Shoshone National Forest, streams have been classed into general types using area, stream gradient, and geology. Streams from selected

types were visited and field data collected. Those in reference condition were analyzed as a group to determine the expected natural variation. This served as a basis of comparison for other test streams: if the test stream characteristic falls outside the natural range of variation, then it was judged to be impacted; otherwise, no impact.

On the Bitterroot National Forest, some 200 stream reaches make up a database for determining stream health comparisons, environmental impacts, and the need for watershed restoration (Decker 1993).

127 Ludwig et al 1988, p68. Three distinct levels of diversity: 1) alpha or within-habitat diversity (i.e. species Diversity Indexes); 2) beta or between-habitat diversity (i.e. changes along environmental gradients); and 3) gamma or large-scale landscape diversity (a composite of alpha and beta diversity). T-Walk focuses on between-habitat diversity.

128 Santa Fe Rapid Bioassessment Workshop taught by EPA in cooperation with USFS R-3 and the New Mexico Environmental Department, 9/29 - 10/2/92. Conversations with Scott Hopkins (NMED) and Dr. Jerry Jacobi (Highland Univ., Las Vegas, NM) identified some common families likely to be found in "very exposed" and "fast water but sheltered" microhabitats. They suggest that sensitivity to chemical (metals) changes would follow the Winget and Mangum Tolerance Quotients, TQ, (Platts, Megahan, & Minshall. 1983. pg 64). (TQ sensitivity: caddis(22) > stone (34) > may (48).

Data from Deer (DC= natural mild metals) and Peru Creek (PC= natural mild metals, transition, acid mine polluted) studies (Ohlander 1987a. And Table 2 from Hurlbutt etal 1989) suggests the same pattern and relative sensitivity. The Tolerance Values in the Hilsenoff Family Biotic Index (FBI) also follows the same pattern and relative sensitivity (EPA 1989).

		FBI	TQ	DC&PC (# families)	
Ephemeroptera (mayflies)	Ephemerellidae	1	48	5	2
	Heptageniidae	4	48	5	2
Plecoptera (stoneflies)	Capniidae	1	32	4	1
	Chloroperlidae	1	24	5	1
	Nemouridae	2	36	5	4
	Perlidae	1	24	5	0
	Perlodidae	2	48	5	2
	Pteronarcyidae	0	24	na	
	Taeniopterygidae	2	48	4	2
Tricoptera (caddisflies)	Brachycentridae	1	24	1	0
	Glossosomatidae	0	32	5	0
	Helicopsychidae	3	18	na	
	Lepidostomatidae	1	18	2	0
	Rhyacophilidae	0	18	5	3

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* Tolerance values selected by EPA for the Hilsenhoff Biotic Index scale 0 to 10 with 0 = most intolerant. Hilsenhoff Family level index was modified by EPA for the Rapid Bioassessment Protocol.

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129 USGS. 1989. Sampling individual rocks for macroinvertebrates (pg 155) includes a reference to Lium (1974). Lium tabulated insects from 420 rocks (8,643 insects) taken from 4 pristine streams in "no-ripple pools", "slight-ripple pools", "fast riffles", and "falls". Stoneflies counted for about 3% of total EPT numbers with mayflies and caddisflies about equal in number. Tolerance Quotients (TQ) have a scale of 2 to 108. For these streams, mayflies show a range of 4 to 72 and caddisflies show a

range of 8 to 108; indicating that neither group is particularly fragil and that stoneflies may be poorly represented in natural systems.

The Family Biotic Index (See FN 128) for mayflies ranges from 1 to 7 and for caddisflies is 0 to 6 (with an overall scale for all insects of 0 to 10). Stoneflies range from 0 to 2. For these streams, mayflies show a range of 1 to 7 and caddisflies show a range of 0 to 4.

130 Kansas Biological Survey. 1985. Krueger and Anderson 1988.

131 Ohlander 1987a. Peru Cr chemistry

132 Hurlbut, Emerick, and Howard. 1989. Peru and Deer Creek mine drainage.

133 Schmal. 1992. Stoneflies tend to be eliminated during and after "channel improvement" projects that straighten or channelize streams.

134 Ohlander 1985. Table IV-2-2 "Summary of Diversity Indices" (EPA 1983 pg IV-2-5) waterbody assessment manual lists 15 diversity indices. Computer simulations of "taxa" were tested for sensitivity to "impacts" using the Shannon-Weiner Index and Sequential Comparison Index.

Fisher & Corbet (1943) suggests that ecosystems vary in their ability to produce species diversity; this "rarity" factor was also tested. A simple count of taxa produced results equivalent to those determined by the other measures.

135 Started 1993. Qualitative method is easy to demonstrate; effects shown include loss of vegetation vigor (resulting in shallow or sparse roots), destruction of vegetation during bank erosion, and/or leaving vegetation high and dry from bed degradation.

136 Citizens for Environmental Quality v. U.S. 731 F.Supp. 970 (D.Colo 1989) directed forest plan to address several watershed issues:

- Failure to identify the technology to be used to prevent irreversible damage to soil resources and watershed conditions (36 CFR 219.14(a)(2)).
- Failure to address compliance with the Clean Water Act (36 CFR 219.23(d).
- Failure to obtain and use current information (36 CFR 219.12(d)).

137 Ohlander 1993b. Review of minimum data and analysis requirements.

138 U.S. WRC. 1983. p6, 13, and 137.

139 USFS R-2 1994. practices

140 Ohlander, 1993c. Litter, fermented, and humus depth recovery.

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WATER RESOURCES ANALYSES

--- *CLEAN WATER ACT* ---

MONITORING and EVALUATION

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- Part 8. T-Walk Training
- Field Supplement

End Date 1/95

REGION 2

CLEAN WATER ACT - MONITORING AND EVALUATION

Part 8. T-Walk Syllabus to Establish Proficiency.
Supplemental Materials for T-Walk Field Techniques
(Companion to Part 7. Syllabus to establish background and rationale)

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April 1994

Notes and Questions

CLEAN WATER ACT - MONITORING AND EVALUATION

Part 8. Syllabus to Establish Proficiency.
Supplemental Materials for T-Walk Field Techniques
(Companion to Part 7. Syllabus to establish background and rationale)

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Comments to:
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CLEAN WATER ACT - MONITORING AND EVALUATION

Part 8. Supplemental Materials for T-Walk Field Techniques

The regional water quality program focus for Part 8 is as follows:

- make monitoring efforts good enough for judicial use under Sec 505.
- train/convince field people to immediately take care of small problems.
- organize and train field people in simple field screen techniques.
- use evidentiary standard questions as basis for all monitoring efforts.
- routine evaluation of aquatic diversity and productivity.
- concentrate on attitude adjustment and training at field level.

Demonstrating compliance to the Clean Water Act is the responsibility of the District Ranger and requires full participation of contract officers, project administrators, and similar persons in charge of field operations. The purpose of T-Walk is to reduce the risk of turning small land stewardship problems into stream health disasters by helping field administrators prepare sound stream health assessments, and if necessary, remedial action plans.

In Part 2, Figure 2.1 "Watershed Information Schematic" shows how various levels of watershed evaluation and accounting fit together. The bottom two titles are:

SELECTION OF VULNERABLE SITES:
-- Select Reference Locations (T-Standards)
-- Stream Reach Characterization (T-Class)

RECORD OF DECISION: Mitigation & Enforcement
-- Implement Monitoring at Selected Sites as planned
-- If **T-Walk** is included, then plan visits: Storm Runoff Control, T-Depth, Tarzwell Substrate Ratio, & Diversity Screen.

Ordinarily, the Selection of Vulnerable Sites with reference location and stream characterization will be done by specialists with training in watershed dynamics and aquatic systems. Once the vulnerable sites, reference conditions, and monitoring protocols are specified by the monitoring plan, then the plan can be implemented by district people.

T-Walk training provides for 2 basic skill levels: 1) specialized knowledge of watershed dynamics and aquatic systems and 2) general knowledge. Normally, the specialists will be the ones to review the EIS/EA alternatives, plan appropriate monitoring, select the reference sites, characterize the stream reach, provide the necessary training, and guide the monitoring and evaluation specified by the Forest Plan and project level Record of Decision. Persons involved with this level already have the field skills necessary to implement T-Walk.

To insure consistency among administrative units, current experience suggests that the specialists get together for periodic field trips to look at local stream conditions and resolve any differences in interpretation among observers. This can and should take place across National Forest and Regional boundaries.

The primary objective of Part 8 is to prepare field administrators to do the T-Walk items associated with Storm Runoff Control, Thalweg Depths, Tarzwell Substrate Ratios, and the Diversity Screen. You will need a copy of the T-Walk form, field manual, and Part 7. The items marked with a ">>>>" are direct from the field manual with excerpts from Part 7 to help refresh your memory.

Quality Control

Competence requires understanding, training, and experience. With a training process that tests - and acknowledges - competence, the agency assumes the burden of defending the method and the evaluations. T-Walk non-specialist training provides for 5 basic phases thought to insure competence:

1 study Part 7 for definitions and rationale;
2 study Part 8 supplemental material before doing the field exercises;
3 complete the field exercises under supervision of a trainer;
4 complete stream health evaluations for representative local streams; and
5 a final check with the trainer to verify results and consistency.

People often make the mistake of assuming that their field work is more or less unimportant and not likely to be given critical attention. Be assured that in a legal contest, ALL aspects will be probed by the opposition to prove that you (and that #@!%# agency you work for) are completely incompetent, that YOUR personal IQ is single digit, and that what ever data and interpretations you have made can not possibly be correct. While you have no particular control over agency nonsense, you can at least do your job with pride of authorship. The witness chair is not fun, but you can avoid hours of intense embarrassment if your work will stand a critical review.

The natural resource profession generally, and the agency specifically, have an obligation to provide tools of good science that address the objectives. The agency is further accountable for proper design, suitable training, and correct application. And it is clearly appropriate for you to pursue agency position and clarification for job elements that you do not understand. If the agency can not explain it to you, then judges are unlikely to understand it either.

Do your quality control thinking first. Current experience shows that 3/4 of most data sets can be destroyed by cross-examination from skilled lawyers and their hired guns. The first reason for this failure is plain carelessness and shoddy work. Do not carry shoddy work forward; either fix it or trash it.

It is critical to formalize routine verification that demonstrates consistency, accuracy, and standard reporting of data and compilations. Treat your work as a signed affidavit attesting to the accuracy and completeness of the information.

The goal of this training (Part 7 & 8) and the encouragement of your best efforts is for you to be able to answer "yes" to the following questions:

Are you competent with regard to data collection?

Did you apply the data collection and analytical methods consistently?

Did you follow the specifics of the monitoring plan regarding type of data and accuracy, times and locations for samples, and data storage requirements?

Did you use equipment that was properly maintained and calibrated?

If you used methods that were not specified by the monitoring plan, were the methods statistically, mathematically, and procedurally valid?

Are you competent with regard to analysis and interpretation?

Was your interpretation logically correct and appropriate to the objective?

>>>> MANDATORY BEST MANAGEMENT PRACTICES

>>>> CWA S404(f)(1)(E) Exemption requires construction and maintenance of permanent and temporary roads and skid trails in accordance with BMPs to assure that flow & circulation patterns and chemical & biological characteristics of "waters of the U.S." are not impaired, that the reach is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. Mandatory S208* & COE [33 CFR 323.4(a)(6)] BMPs are paraphrased as follows:

>>>> 1 limit road & trail system to the minimum feasible number, width, and total length consistent with the specific operations, topography, and climate;
>>>> 2 except at crossings, all roads and trails* shall be located sufficiently far from streams or other water bodies to minimize discharges; [* -- S208 and S304 add trails];
>>>> 3 crossings shall not restrict the passage of expected floods flows;
>>>> 4 fills shall be stabilized during & after construction to prevent erosion;
>>>> 5 minimize equipment disturbance in "waters" outside construction zone;
>>>> 6 minimize vegetative disturbance in "waters" during and after construction;
>>>> 7 road crossings shall not disrupt the movement of resident aquatic species;
>>>> 8 take borrow material from upland sources whenever feasible;
>>>> 9 the discharge shall not take, or jeopardize the continued existence of, a T&E species, or adversely modify or destroy critical habitat;
>>>> 10 avoid discharges into migratory waterfowl habitat, spawning areas, and special aquatic sites [40 CFR 230.10(a)(3)]; special aquatic sites include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, and riffle and pool complexes. [40 CFR 230.3(q-1)].
>>>> 11 discharge shall avoid areas in or near public water supply intake;
>>>> 12 discharge shall avoid areas of concentrated shell fish production;
>>>> 13 discharge shall avoid National Wild and Scenic River System reaches;
>>>> 14 discharge material will be free from toxic pollutants in toxic amounts;
>>>> 15 all temporary fills will be removed and restored to original elevation.

<u>Background Key Ideas</u> "... are not impaired...."

EPA's stream health definitions and S404(b)(1) guidelines are used to determine "impairment." The road and trail exemption criterion of "no impairment" is satisfied if mandatory BMP's have been installed, that losses in stream health are no greater than that allowed by applicable NWP's, and risk of "significant degradation" is low for both the short as well as the long term.

The 4 reasons that fail to comply with S404 at 40 CFR 230.12(a)(3) are:
- -- selected alternative is not the least damaging practicable alternative;
- -- selected alternative does not include all appropriate and practicable measures to minimize the potential harm to the aquatic ecosystem;
- -- selected alternative violates State or Federal environmental laws; or
- -- there is insufficient information to make a reasonable judgement.

The first line of defense, therefore, is the design of alternatives that avoid, or at least, reduce the risk of problems. After the project has begun, make a habit of looking around and fixing problems as they develop. For example, since field operations are subject to S404 enforcement, at least fix up conditions, such as roads or trails that discharge sediment directly into a stream, that are obvious and can be easily used to generate public complaint.

Exercise.

Maps are necessary working tools and continue to be a point of focus for questions of insufficient information. The information needs to be commensurate with the type of impacts expected. It is often possible to anticipate whether a map will meet the needs just by knowing purpose and scale. As you look through the list of BMP's remember that this S404 issue includes waters of the U.S., special aquatic sites, terrestrial TES critical habitat, public water supply intake areas, migratory waterfowl habitat, spawning habitat, Natl Wild and Scenic River segments, heavy use sites, high hazard lands, roads, trails, and other sediment sources, and other pollutant source areas. Go through the maps referred to below and answer the two questions for each type of map:

??1 Does the map provide enough scale and detail to support a finding of no significant impact as related to the road and trail system?

??2 Mark those maps, that if made part of a timber sale contract (tsc), would meet S404 requirements implemented under B6.5 "protected streamcourses" for "waters of the U.S."? (Why is this a tricky question?).

1/2"/mile Forest Recreation map?	Y	N	tsc
2"/mile status planimetric map?	Y	N	tsc
4"/mile blow-up of 2"/mile planimetric map?	Y	N	tsc
1:24000 orthophoto on USGS stnd topog	Y	N	tsc
1:24000 orthophoto, USGS topog, field verification?	Y	N	tsc
4"/mile black and white aerial photo?	Y	N	tsc
1:24000 USGS standard topographic	Y	N	tsc
4"/mile blow-up of 1:24000 USGS standard?	Y	N	tsc
1:24000 USGS stnd topog w/ field verification	Y	N	tsc
4"/mile (from 1:24000 USGS) with field verification?	Y	N	tsc
1:24000 USGS base USF&WS wetlands overlay?	Y	N	tsc
4"/mile (from 1:24000 USF&WS) with field verification?	Y	N	tsc
6"/mile (from 1:24000 USGS) with field verification?	Y	N	tsc

Connected Disturbed Area

One better way to monitor BMP effectiveness is to move toward methods that help integrate the various factors that drive the concentration and dispersal of pollutants. Current experience suggests that "connected disturbed area" (CDA), as a measure of high runoff areas that drain directly into the stream system, is a reasonable compromise between lots of detail and a relatively easy field tool.

We expect CDA to help define changes in land use runoff characteristics more rapidly, to identify and take credit for pro-active management in reducing pollutant source areas, and finally help set a limit on how much is enough.

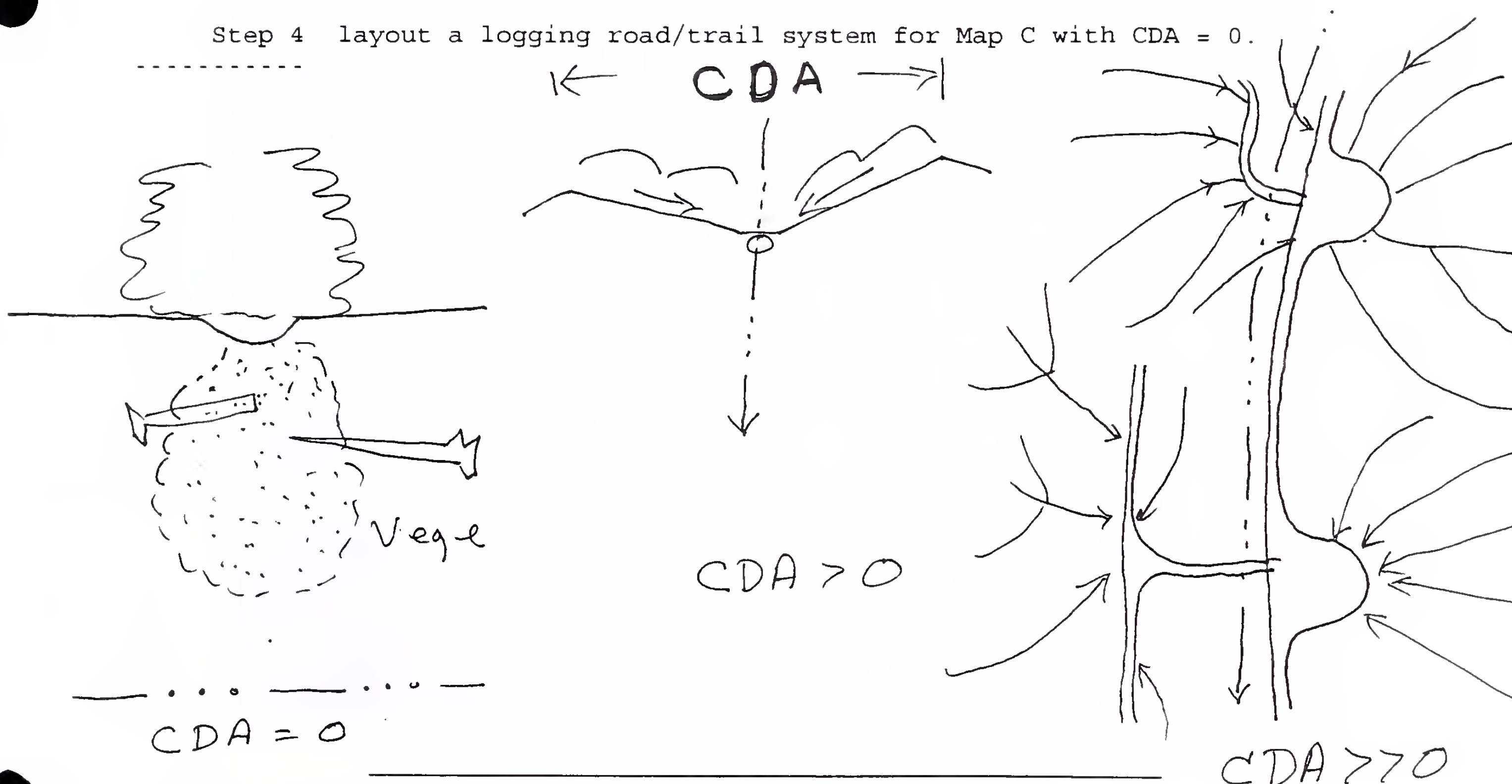
Exercise:

1) Review the maps and aerial photos. For each example:

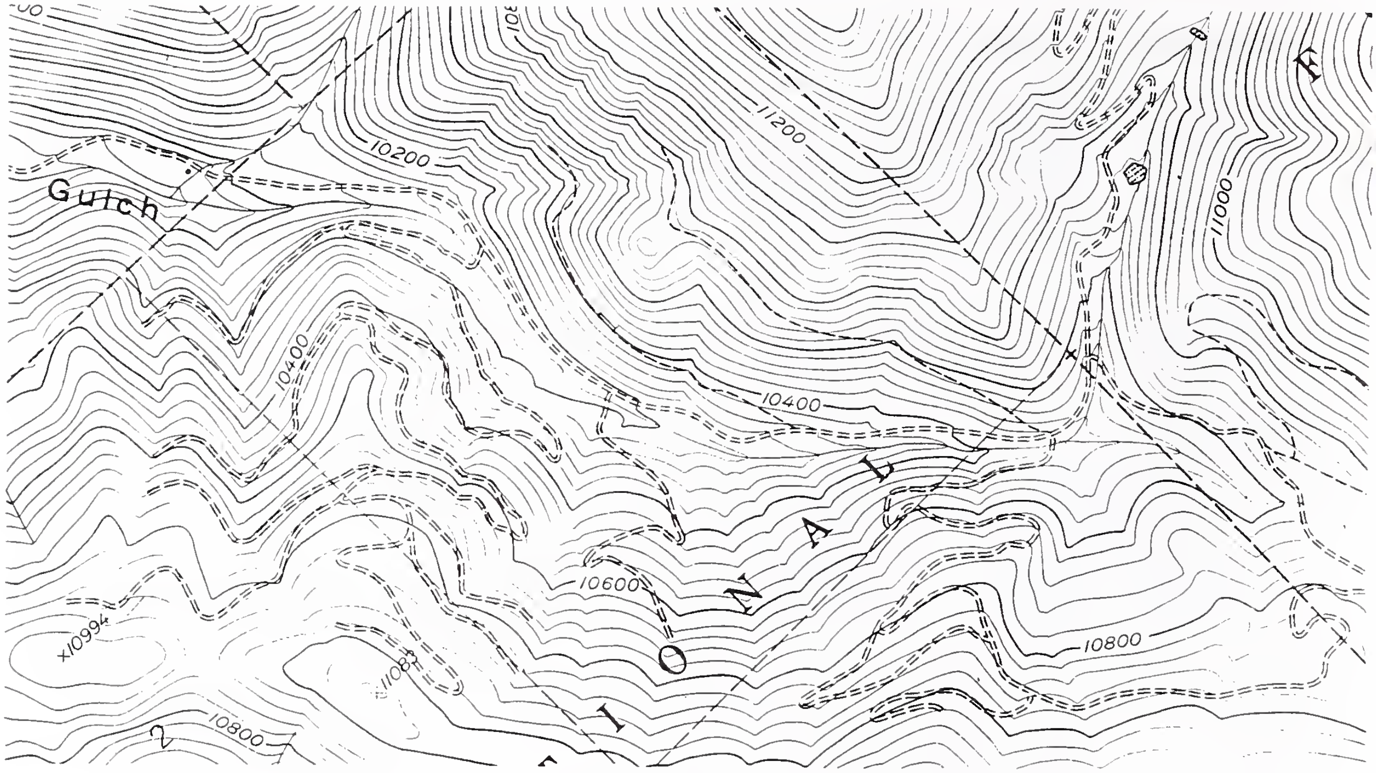
Step 1 color in the "waters of the U.S.".
Step 2 color in the road/trail area likely to be a sediment source.
Step 3 mark the existing CDA areas and note (none, low, or high).

Map Example A	CDA = 0	CDA > 0	CDA >> 0
Map Example B	CDA = 0	CDA > 0	CDA >> 0
Map Example C	CDA = 0	CDA > 0	CDA >> 0
Photo Example D	CDA = 0	CDA > 0	CDA >> 0
Photo Example E	CDA = 0	CDA > 0	CDA >> 0

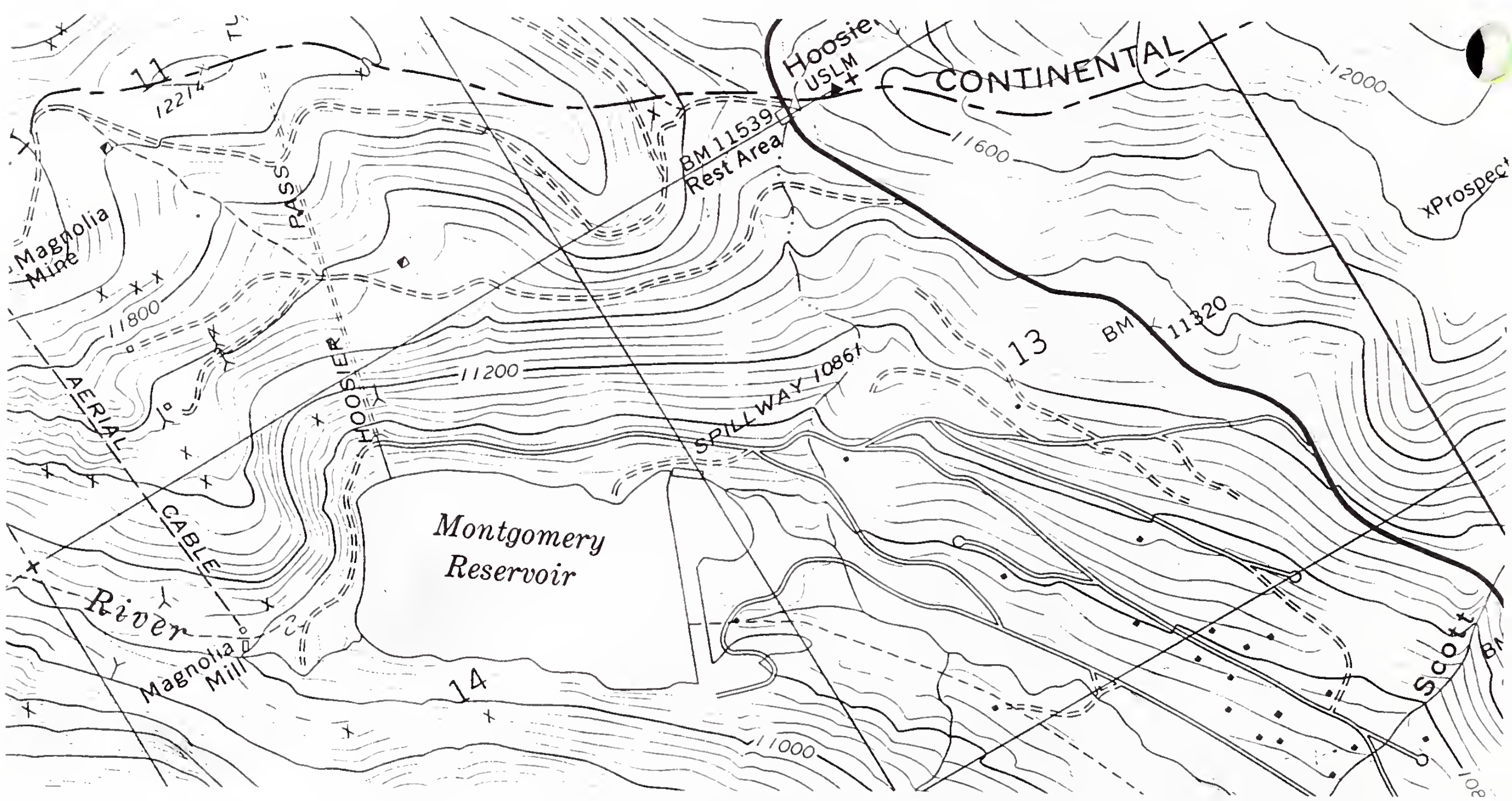
Step 4 layout a logging road/trail system for Map C with CDA = 0.



Map Example A.



Map Example B.



Map Example C.

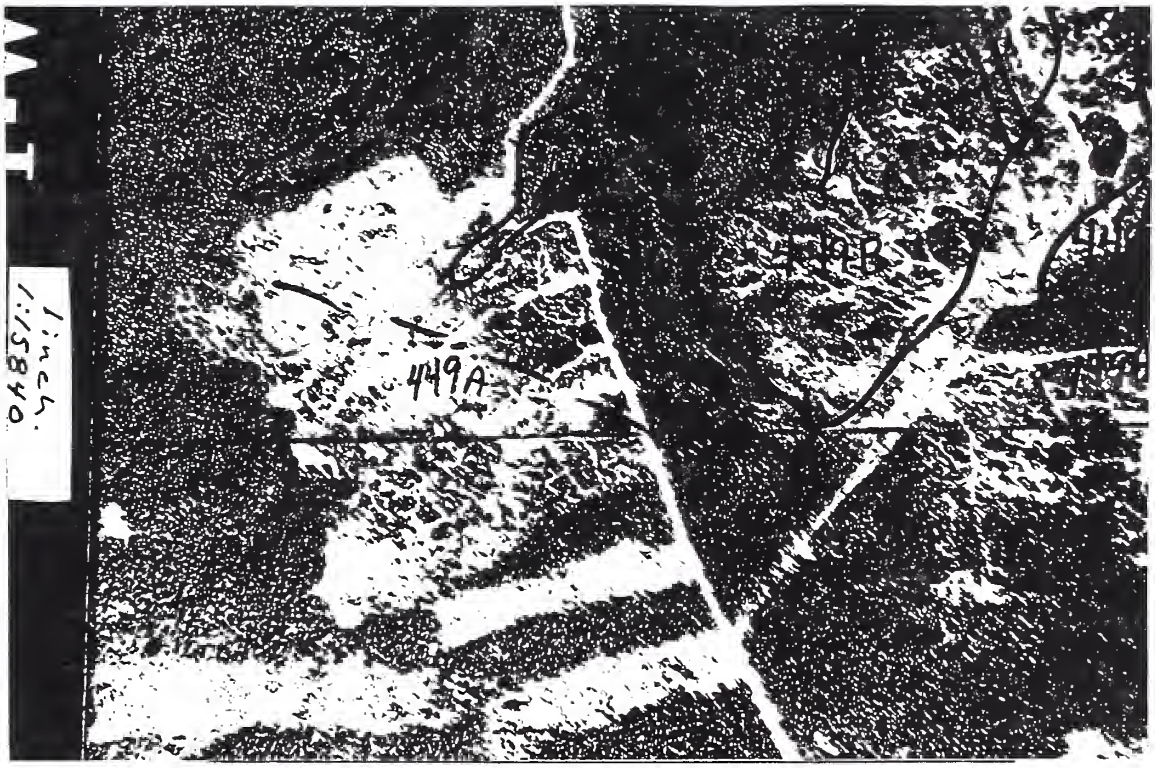


Photo Example D.

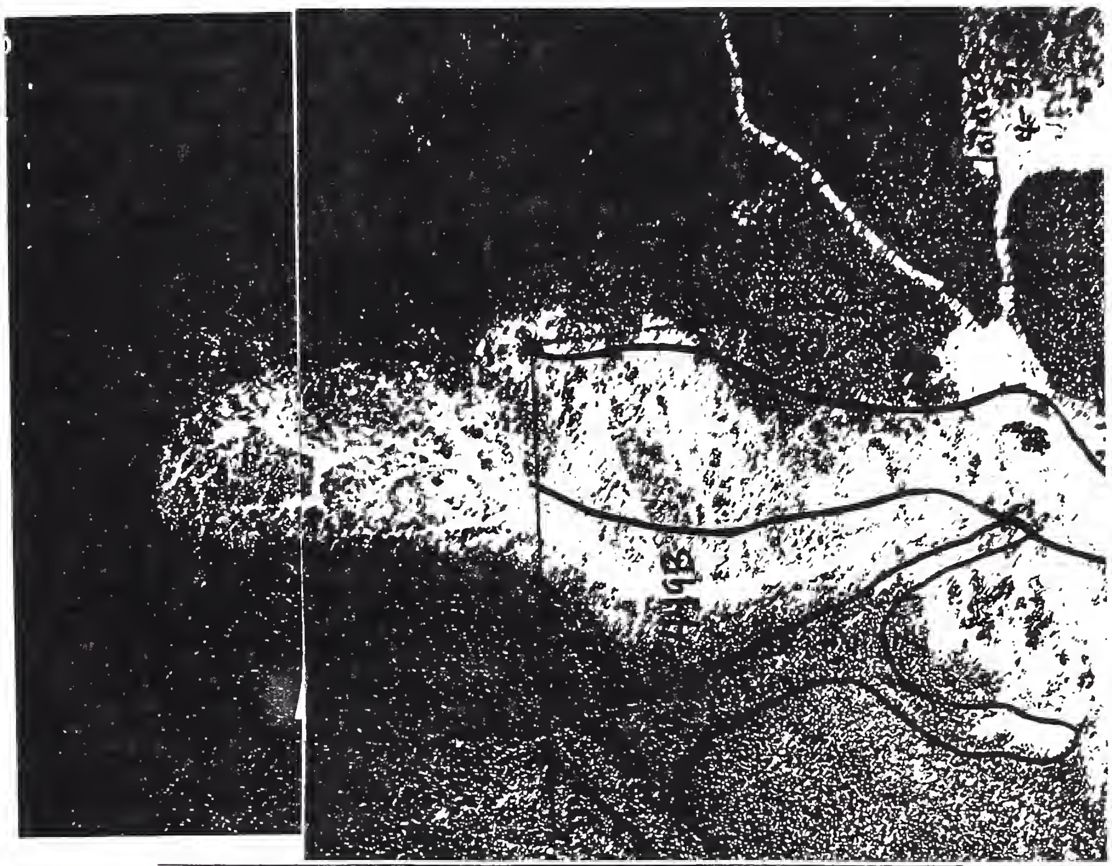


Photo Example E.

Equipment

Training for equipment use includes these commitments by the trainee:

1. will participate in hands-on use of equipment;
2. will spend time with a trainer using necessary equipment; and
3. will work several streams to perfect techniques.

Background Key Ideas

Safety is of primary importance in getting the water quality job done. You will be collecting information on stream banks and stream beds; and it is not unknown for such areas to be slippery, full of ankle twisting cobbles, loaded with short knee jerk stubs, and similar type hazards.

Comfort and ease of collecting good data with hassle free equipment is also of importance, since the more uncomfortable you are, the less likely that you'll do a good job. You need to do a good job; water quality is a legal issue and you are the expert witness and subject to lawyer bites for the sites you visit.

>>>> Equipmt: Waders, 5x hand level, T-Stick, survey rod, 5-10x hand lens, 100' measure, insect repellent, M+calc, % clinometer, map, pins, C/F thermometer, trowel, snooper, cord & line level. Optional: Camera, mm ruler.

Dot tally -- made up of corner dots, :: = 4; lines that connect dots into a box; and diagonals; i.e. [X] = 10). [X][X][X]:. = 33; [X] [] = 18.

Calculator square root key is (^0.5). So A^3/4 is (AxAxA)^0.5 ^0.5.
What is 3^(3/2) = 2.28; 5^3/4 = 3.34; 11^3/8 = 2.46

Calculate slope using the 5 power hand level and roll-up rod.

Calculate slope using the cord with line level for short distances (<50').

Practice calculations on a M+ calculator for pace transects.

Practice use of the % clinometer for road grades and side hill slopes.

Separate bag for camera, film, and name board. Practice marking features for photographs. Discuss FIELDSCRIPT.

Measure and record thermometer data.

Explain the use of a "snooper".

Explain the use of the 5' T-Stick.

Photographic evidence - *FIELDSCRIPT* keyword -

Based on what it takes to get good photograph exhibits for testimony in Court. Major problems result from poor visual quality, lack of important detail, or lost negatives. Steps recommended to improve photographs used for evidence:

- - Use a good adjustable camera; inexpensive ($150) "auto" are too limited.
- - 35mm camera, 35-70mm macro zoom & polarize filter is a good choice.
- - Take Polaroid as 2nd camera for immediate documentation.
- - Use a separate bag for photographic equipment.
- - Train all field people, not just those with the camera.
- - Plan site visit relative to satisfactory light conditions.
- - Sketch out a story line to control the photo sequences.
- - Anticipate likely comparisons ; show the same features and scale.
- - Concentrate on field marking/identification of features.
- - Note on field form the roll/frame, date and exact location.
- - Focus, depth of field, and light must be understood.
- - Horizontal views give better scale and depth than do verticals.
- - Use a tripod (or unipod) for shutter speeds less than 1/125s.
- - Develop prints for cool colors and features rather than people.
- - Favor slides; can be used for prints as well as slide shows.
- - Label, index, and store. Label includes date, place, what, and who.

F*I*E*L*D*S*C*R*I*P*T key word to script evidentiary quality photos:

F Flash: Add extra light in the 6 - 14' range and to penetrate shadows or focus attention on near ground. Slave units are also available.

I Identify: Essential. Describe time, place, and feature(s) in a bound field book; include signs (or name board) in the picture. Mark field points with a survey rod, tape, stakes, or white cord with eye pins.

E Evidentiary: Storyboard the objective to detail when, where, how, what, who, why. If this is for several sites, preprint the checklist.

L Light: Plan ahead for the sun position you want. Best results are with narrow lens openings and rapid shutter speeds; poor light (slower shutter speeds &/or wider lens openings) can be partially compensated by faster film speed. Limit shadow ratios (horiz to vert) to less than 1. Reduce shadow/bright contrasts (umbrella) for ground detail. Use tripod. ASA 400 is a good speed; may need ASA 1600 with a polarizer in low light such as photographing streams in a forest setting.

D Depth: Visualize the 3-dimensional perspective. Setup to take advantage of shadows, linear features, and a balance in contrasts to get the 3-D effect. What depth of field do you want? A wide lens opening results in center piece in focus and out-of-focus fore and back ground; a narrow lens opening will retain more fore and background in focus. Use a tripod on shutter speeds less than 1/125s. Avoid setups with sun in front or behind camera; these tend to produce 'flat' shots.

S Scale: Landscape (horizontal) tend to provide better 3-dimensional scale elements than those in vertical. Incorporate scale with subject, like a tree. If you need to add scale or if a quantitative scale is needed, add a linear scaler that fits the dimension of the main feature.

C Color: What is the mixture? Look at the basic color group of the target feature. Under normal daylight conditions, the balance should be okay; however, late afternoon photos in the fall tend toward reds and oranges. You can correct with filters to help bring out blue and green tones.

R Reproduction: When the film is processed, request that printing concentrate on features and colors that emphasize the objective. Plan ahead for copies, matte or gloss finish, and slide show presentations.

I Indexing: Pictures fill such a valuable role in presentation that being able to find the print as well as the negative (or slide) is of great consequence, but trash the poor stuff first. After processing, write the photo date (yrmoda) on the negative folder(s), sort prints in order of exposure, write date and frame sequence on each print (ie 910809.53 is the 53rd photo taken on 8/9/91). Negatives for the same day are put in the same envelope and filed numerically. Storing the negative folders by date, makes retrieval easy. The date-counter number provides an easy label for indexing text material. Indexing and storing slides is less trouble because the mounts protect the film and is already dated and numbered. Writing a sequence number, then storing in numerical order in steel trays (300+) with a subject list works well.

P Protection: Protect prints in 8x10" plastic sheets that can be stored in binders (avoid vinyl for archiving). Protect slides in 8x10" plastic sheets; for long term storage use steel trays. Protect negatives in individual glassine negative holders (in 6x9" envelope; envelopes stored by date in file box). The recovery of negatives and slides in good shape after 25 years is the mark of a good storage system.
Plastic sheets for 3.5 by 5" standard prints provides 4 pockets; can store 24 prints - 6 in each pocket. A full 2" ring binder can be closed tight enough to prevent the plastic sheets from sagging. Number the sheets with the date (yrmoda) and set up a simple location index.

T Text: Start each print or slide with index date (yrmoda.##). Transfer notebook entries to the back of photo prints (& edge of slides). When there are several photos of nearly the same thing, use a word processer (global replace) to easily build labels for the photo back. Include date, where, who (initials at least), what, special notes, and notebook page reference.

Notebook name board: 8.5x11x0.5" flat black vinyl notebook; 3+ sheets of non glare transparent plastic 2x2" slide file with 5 rows of 4 slides; 2x2 water proof (rite-in-the-rain) laser print white-on-black characters. Letters in simple block style that are easiest to identify on negatives include 20 letters and 5 numbers: B D E F G H I J K L P Q R S T U V X Y Z 2 4 5 6 8. An upside down V gives a sharp A, a lazy U for C prevents confusion with a G or O, a face down E gives a sharp M, a lazy Z gives an N, an upside down Q gives an O (& zero), a face up E gives a sharp W, an I gives a 1 (& -), an backward E gives a sharp 3, an upside down L gives a sharp 7, and an upside down 6 gives a 9. Use 1 plastic sheet to store 20 letters (B to Z), the 2nd for numbers, +, /, elevations (11 12 13 14), and aspects (SE SW NE NW). The extra sheets can be set up as needed for the site photographs.

>>>> **Scale for Impact Analysis** - Ideally, center a 40 acre evaluation cell on the major intersection of the management activity and the stream. This divides into two 1/8 mile (660') stream reaches and allows the above reach to be compared to the below reach for an estimate of impact. In field use, reaches may be longer or shorter and located to get the best information.

>>>> This manual follows the normal steps used for site analysis: begin with road & upland conditions, track the effects into the stream, & estimate current & future stream health, restoration, and follow-up monitoring.

Need to emphasize that T-Walk's orientation is to the time and space of your particular objective(s) rather than to a preconceived notion of what data "should" be collected. Stream health is the bottom line, but there are a lot of ways to get there including some common sense observations that allow you to anticipate stream health without necessarily making all of the measurements. For example, there is nothing wrong with stopping at a bridge, looking at the stream, and determining an approximate level of stream health. If it looks bad, then perhaps the best use of your time may be in restoration work, rather than defining decimal points of damage.

From the perspective of your job, list some disadvantages of an incremental process and why it might fail to provide good data?

Exercise:

Draw a watershed with streams and locate 4 land use activities (your choice); assign some level of erosion hazard risk (high or low) to each activity. Assume that road construction is ready to start, where and what would you monitor to stay on top of the developing project?

___ Storm Runoff Control
___ Site Protection
___ Concentration Factors
___ Dispersion Factors

___ Thalweg Depths

___ Tarzwell Substrate Ratio

___ Channel Materials

___ Channel Physics

___ Diversity Screen

>>>> <u>Stream Health</u> - The purpose of T-Walk is to determine Stream Health for each stream based on its <u>own</u> capability defined in terms of diversity, stability, & productivity. The Stream Health evaluation strives to answer three questions:

What is it now? What should it be? What has to be fixed?

The evaluation is based on the limiting factors or habitat conditions needed to support local species of trout and provide answers to the questions.

The Aquatic Life Health scale for diversity and stability uses "Robust" as the standard with all other classes defined as incremental changes from "Robust":

Robust	Comparable to the best situations unaltered by man; all regionally expected species for the habitat and water body size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Adequate	Fish and macroinvertebrate species richness somewhat less than the best expected situation, especially due to loss of most intolerant forms; some fish species with sub- optimal size distributions or abundances; trophic structure shows some sign of stress.
Diminished	Fewer intolerant forms of fish and macroinvertebrates are present. Trophic structure of the fish community is more skewed toward an increasing frequency of omnivores; older age classes of top carnivores may be rare.
Impaired	Fish community is dominated by omnivores; pollution tolerant forms & habitat generalists; growth rates and condition factors commonly depressed; few top carnivores; hybrids and diseased individuals may be present. Pollution tolerant macroinvertebrates are often abundant.
Precarious	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, physical damage, and other anomalies regular. Only tolerant forms of macroinvertebrates are present.
Catastrophic	No fish, very tolerant macroinvertebrates, or no aquatic life. Ecological upset and collapse; retrogression.

The numerical thresholds for six production classes are indexed on a ratio scale of 0 to 1 calculated as projected (or existing) divided by expected production under long term natural - **Reference** - conditions. By using a ratio, many different units of measure are applicable. The terms are commensurate, the ratio dimensionless, and "1" is the best ratio.

Stream Health (table) is a combination of the Aquatic Life Health class and production. Stream Health is determined by the lowest of the two scales. This improves our ability to determine what the limiting factors are, so further damage can be prevented and restoration planned.

Stream Health Classes

(Combination of aquatic life health and carrying capacity ratios)

Aquatic Life Health Class	Ecological Carrying Capacity Ratios 1.0-0.9	<.9-0.7	<.9-0.7	<.7-0.5	<.5-0.3	<.3
Robust	ROBUST	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Adequate	ADEQUATE*	ADEQUATE*	Diminishd	Impaired	Precarious	Catastrph
Diminished	Diminishd	-----------	------------------>	Impaired	Precarious	Catastrph
Impaired	Impaired	-----------	-----------	---------------->	Precarious	Catastrph
Precarious	Precarious	-----------	-----------	-----------	---------------->	Catastrph
Catastrophic	Catastrph	-----------	-----------	-----------	-----------	---------------->

* Adequate only applies to legally impacted stream reaches.

If the biological system has not been overwhelmed by chemical pollution, the physical habitat factors and the ability of substrate, cover, flow, depth, pools, and riffles to support existing aquatic life becomes the key evaluation.

Reduced habitat complexity and the loss of pool depth tends to truncate diversity of both species and age classes in a system; this often results in systems with a few species, limited age classes, and reduced carrying capacity.

In winter, fish abundance and winter survival is often limited by the amount and condition of microhabitats and overhead cover associated with large woody debris and treeroots. During high flows, stable material provides protection from peak flow velocities and during low flows provides cover and maintains the pool depths needed for survival.

For many forest systems, large woody debris and treeroots provide major structural control in streams. Large amounts of material tend to produce stream features with numerous, small distorted pools, short step-like riffles, multiple channels, backwaters, ponds, and combinations of slack and plunge pools associated with large embedded pieces.

In channels that have not been blown out, fisheries cover is provided by small and large woody debris, rootwads, undercut banks, and deep water. Stable material increases channel complexity by its influence on the distribution patterns of velocity, bars, and pools as well as the distribution and retention of organic matter. Pools and undercut banks created by stable boles or rootwads can be up to 10 times more productive than similar, but unstable, sites.

In blown out channels, cover consists of rocks, boulders, and surface turbulence. Loss of stable instream large woody debris reduces channel structure and complexity, reduces total number of pools and pool volume, releases large amounts of previously stored sediment, and reduces the system capacity to store and process organic matter. Unstable debris tends to create large, but infrequent, jams and piles.

Storm Runoff Control

Storm Runoff Control training includes these trainee commitments:

1. learn the definitions and how they apply to storm runoff control;
2. study photographs of different land and soil conditions;
3. spend time with a trainer looking at local sites;
4. work several areas to perfect techniques; and
5. call the trainer back for a consistency check.

Background Key Ideas

Land stewardship requires that the land be "used within its capabilities and treated according to its needs." The cost and risk involved with watershed development determines the nature of the hydrologic analysis; the objective of which is to minimize risk by conservative design and good construction. Both high-cost and high-risk projects require special geologic and hydrologic studies to avoid unnecessary risk, but the more typical analysis can focus on watershed characteristics, precipitation, and runoff from existing and planned activity.

Land use projects are planned using the NEPA process. There is substantial effort spent in obtaining and analyzing resource information in order to make the plans worthwhile and viable. However, there will also be information gaps that can only be filled in by field inspection. Part of the monitoring job is to know the planned elements for resource protection, problems to be expected, and what to do if they are encountered.

One major value of T-Walk is that the objective itself is focused on avoiding problems to start with. Attention is directed to the more vulnerable sites and a micro level of detail that is not usually covered by the plan. Field people need the latitude to find ways to avoid problems - even if some plan elements have to be changed, delayed, or subject to extraordinary mitigation.

Current experience suggests that certain problems can be anticipated:

- Activity areas open to operator or contractor interpretations;
  - roads to be located by the logger;
  - channel improvements to be located by the highway department;
  - topography or road systems that encourage draw bottom skidding.
- Permanent roads with grades over 6%.
- Disturbed areas on south aspects or on droughty soils.
- Disturbance of areas with less than 70% natural vegetative cover.
- Roads or cuts along side hill slopes of 50% or greater.
- Canopy removal on soils with less than 0.1' litter and humus depth.
- Disturbance of areas next to streams that lack an adequate buffer.

Connected Disturbed Area. The previous list is only useful in the context of training and building awareness; the welter of detail would soon get in the way of good field application. Besides, there is a better way to keep track of what areas create risk for stream health.

In 1986, the SCS updated their technical manual on urban hydrology. The manual now includes improved methods for hydrologic analysis for urbanized areas with extensive pavement, roofs, concrete gutters, and storm sewers. Where such areas are connected to the natural stream system, large volumes of storm water rapidly runs off and results in accelerated peak flows. The SCS uses the "Connected Impervious Area" as a measure of urban watershed response to storm events.

The "Connected Disturbed Area" is a parallel thought, except that it applies to high runoff areas that may be paved, but are more likely to be dirt or gravel roads, mine spoil, denuded areas, highly compacted by heavy equipment or livestock grazing, or areas rendered nearly impervious from fire effects.

Because of the causal relationship between storm runoff and soil erosion and the damage to stream health, field studies need to center on determining Connected Disturbed Area and finding ways to "disconnect" it from the stream, such as by diverting road drainage through vegetative filters or into settling basins.

A minor exercise:

First draw 2 duplicate watersheds with a stream network drawn to the ridge.
Mark 4 destinations (same spots on both watersheds).
Road access must be equal to watershed boundary length; start anywhere.
Wshed 1: draw in a road system that MAXIMIZES Connected Disturbed Area.
Wshed 2: draw in a road system that MINIMIZES Connected Disturbed Area.

Can you conclude that Stream Health will suffer badly in Wshed #1? _____

Did any roads cross streams in Watershed 2? _____

- If crossings meet the Forest S&Gs then the Nationwide 404 permit covers your activity, and any damage is "insignificant" by definition. What are the Nationwide 404 permit limits for bank damage and fill material?

- Road and trail construction compact the soil and concentrate storm flow. What practices would help decrease the volume and velocity of water runoff, and/ or decrease the flow's sediment carrying capacity?

- What vegetation and erosion control practices will be used to protect the soil surface and decrease particle detachment?

- What practices will be used in reducing the amount of soil exposed during road construction, harvesting, and site preparation operations?

>>>> I Site Protection - excluding roads or trails, how well is the site protected? Make a contour transect across the more exposed or beat up sites and report on:

>>>> **Bare soil patterns** - show worst water concentration patterns as small & large patches that are not connected, overlap, and rills or gullies.

>>>> **Ground cover %** - total area % of LFH plus live ground cover.

>>>> **LFH layer depth**, ft - long term depth of litter + fermented + humus.

Vegetative species, age, density, burning, grazing, cutting, and logging effect the physical characteristics of surface soil and the resulting runoff. Bare soil patterns are acceptable to the extent that they are not now, or likely to be, connected to the stream system. The more or less 10' square patch (small) caused by normal on-site equipment use rarely creates runoff problems, but as patches become larger and connected by trails or depressions, then storm runoff control becomes more difficult and remedial action more likely to be necessary.

Litter is necessary to provide erosion protection, insulate the soil, prevent too rapid oxidation of humus, and provide a food source for humus-forming soil life. Humus depth and porosity is very sensitive to land-use; normally it is porous with high infiltration rates and detention storage capacity, but improper use can result in a compacted layers. Concrete-like frost develops under felty mors or compact firm mulls and greatly reduces infiltration. In contrast, porous humus types develop a stalactite frost may actually improve infiltration.

Terminology used to describe humus for hydrologic response, dates back to the soil survey handbooks of the 1950's and 1960's. Since that time, soil survey terminology has greatly changed and the descriptions of humus layers are no longer the same as the terminology still used by hydrology. The old terminology is used here because it is more descriptive and easier to talk about:

Litter, L = undecomposed leaf and twig fall; depths of 0.02' to 0.04' (1/4-1/2") are needed to protect and maintain the humus layer.
Fermented, F = partially decomposed and fermented.
Humus, H = well decomposed and pieces are not distinct.

Mor humus - F and H layer present; no mixing of mineral soil; transition from H to mineral soil is abrupt. LFH depth = L + F + H. Generic terms include thick, thin, granular, greasy, or felty mors. Some examples:

a Felt mor - thin layer; partly decomposed, laminated or compressed litter; interwoven by fungus mycelia (and roots). Shows improper land use or fire.
b Ligno-mycelial mor - "raw humus" derived from forest Fermented layer interwoven by fungus mycelia (and roots).
c Lignified mor - On nutrient depleted soils, conversion stops at inert lignified mor that ties up nutrients in a decay-resistant fungus mycelia causing a breakdown of the natural self-fertilizing mechanisms.
d Moss mor - transition between forest mor and peat.

Mull humus - with or without an F layer; no pure H layer; mineral soil mixed with organics (A1); gradual transition to next horizon. LFH depth = L + F + A1. Terms include loose or firm mull; fine, medium, coarse mull. Some examples:

- a Velum - previous year's loose or friable litter on a pale-colored eluvial (bleached) horizon impoverished in nitrogen (usually below 0.05 %) caused by intense leaching and active micro-organisms.
- b Crypto-mull - warm and moist sites on fine-textured soils; like velum except pale-colored soil enriched in nitrogen (from 0.1% up) caused by humate infiltration.
- c Microbiotic mull - gradual decay; shows coarse leaf fragments in localized "lumps"; finely aggregated, massive, or single-grain structure.
- d Earthworm mull - prototype and best-known of zoogenous humus. Worms cause the mixing: large worms= coarse or crumblike aggregates; small worms = fine, grainlike aggregates. Mostly in fine-textured soils with ground water or seepage.
- e Arthropod mull - crustaceans, mites, millipeds, and insects cause surficial accumulation; brownish bran, ground coffee, or black sawdust; transition to mor type; mostly calcareous soils.
- f Sward - = "turf" and "sod"; vegetable mold filled with the roots of grass and other plants. Several types recognized: prairie, alpine, and grassland or more detailed as: gramma, fescue, and bunchgrass sward. Organic matter ranges from 1% to 20%.
- g Duff mull - stable forest type transition to mor. Includes forest Litter(L), Fermented(F) or "duff", and a mixed mineral humus layer caused by microbes, worms, and arthropods.
- h Fen mull - sparse forest litter and a mucklike layer of mineral and finely dispersed organic material that is usually saturated with calcium and magnesium (mildly acid or alkaline). Formed under hydrolysis and anaerobic conditions of water logged soils.

How to Review the Photos

1. Study Plates L1 - L4; and, for this exercise, assume that the color changes reflect real differences in the soils. Use a hand lens to really look for litter layers, total humus depth, and for distinct or gradual lower boundaries.

2. For the table below, mark the humus type and a subtype from the list.

Site	Soils Photo Pair		Litter Depth'	LFH Depth'	Topsoil Depth'	Humus & subtype (circle & abbrv)		
L1	415	416	0.01	0.15	0.9	mor	mull	________
L1	450	451	0.02	0.11	0.6	mor	mull	________
L1	456	457	0.02	0.11	1.6	mor	mull	________
L2	413	414	0.07	0.12	0.4	mor	mull	________
L2	442	441	0.06	0.07	0.4	mor	mull	________
L2	487	486	0.12	0.2	0.5	mor	mull	________
L3	489	488	0.05	0.12	0.25	mor	mull	________
L3	498	497	0.08	0.18	0.9	mor	mull	________
L3	502	501	0.05	0.08	0.6	mor	mull	________
L4	920501.9		0.06	0.25	1.0	mor	mull	________
L4	920519.19		0.02	0.04	0.6	mor	mull	________

3. Plate L4 920519.18, -.19, and -.20 are from the same 1965 clearcut that was followed by site preparation that removed most of the surface litter. Massive amounts of frost heave is common when winter snows are too thin to insulate the soil. Under these conditions, a nearly impervious concrete frost is formed; and under these conditions an ordinary spring storm will result in accelerated runoff with great potential for mass failure and soil erosion.

Starting with a forest soil of LFH depth of 0.2', the soil hole shows the effect of site prep on the humus and litter layers. Finally (#-.20) shows extensive shallow surface flow that has removed the fines on this side hill (which is not a road). Shallow surface flow on site prep areas is common in the spring.

Field Exercise

There are 2 stages to this exercise: first, select the activity area and imagine what the site looked like just before the activity took place. Based on what you can see and guess, write a short land use history, including the soil and vegetative conditions resulting from the last major activity.

Second, run a transect through the worst part of the area and look for spots that are at risk from soil erosion, or continue to be high runoff sites. As bare soil patterns shift from covered to small patches to large patches to overlapping areas, the possibility of site damage accelerates, and needs to be compensated for with concurrent site treatment. Any site that shows existing rilling or gullying requires immediate treatment.

Ground cover % is a count of vegetation (litter, branches, slash, downed timber, and all live plants) divided by the total count. Many miscounts can be avoided by consistently defining litter as => 0.02' (0.25") thick. A simple dot tally with both total and cover works well and reduces mistakes.

For a measure of the LFH depth, choose a site that is both undisturbed and typical of expected conditions; avoid seeps or swales or similar areas that accelerate the normal LFH development. When you cut through the top layer, keep the structure in place so it can be measured. Do 5 or 6 samples and use an average for the LFH depth. Remember the measurement is in feet, not inches.

What % of the study site has an adequate litter layer?

Compare answers with other students. How much difference is due to different observers and how much is due to selecting different routes for the transect?

>>>> II Concentration factors -
>>>> How are pollutants brought together and concentrated?

>>>> In particular, roads, trails, and any corridor that modifies natural drainage changes timing, volume, and peak flow delivery to streams; sediment is often carried with it.

>>>> For **Design roads**, **Temporary & primitive roads**, **Corridors & trails**, & **Connected Disturbed Area Acres**, record slope %, distance between cross drain features, and disturbed area channel length.

>>>> Summarize **Surface**, **Road Acres**, **Rill depth** (0.1' depth for the most eroded surface), **& Connected Disturbed Area Acres**.

>>>> Mark "at-risk" if (CDA^0.5)*Slp%/Wid' > 3.6. (Slp% & Wid' is at peak flow wetted perimeter).

The risk of gully erosion can be assessed by comparing measured values against the critical 1.5 Stream Power value. Field values less than the Stream Power threshold value represent little risk, while those that are greater reflect increased risk. The SP = 1.5 threshold equation is:

SLOPE%/WIDTH' = 3.6 / (ACRES ^ 0.5) where:
Slope%/Width' is a ratio that combines
Slope% = clinometer read as %, i.e. 6% is 6.
Width' = wetted perimeter at peak flow, feet.
Acres = drainage area (high runoff or CDA), acres.

Conditions where -- (CDA^0.5)*Slp%/Width' > 3.6 -- defines at-risk for T-Walk evaluations of sites that may develop eroded characteristics if diverted, blocked, or trailed.

Exercise

Given a CDA = 1.5 acres, valley slope of 3%, and width 15':

Calculate the SP factor:____________________. Is the site at-risk? Y N

Calculate the SP factor for 2' width:__________. Is the site at-risk? Y N

Same as above but CDA = 5 acres: SP = __________. Is the site at-risk? Y N

At what amount of CDA does the risk factor just equal 3.6? __________ Acres

Field Exercise

Select a road drain and determine the field CDA, SP, and at-risk.

>>>> III Dispersion factors -
>>>> Where do pollutants and sediments end up? For example, stream impacts from excess sand remain until they are flushed into deep water or dredged out. Objective: keep pollutants out of water to start with.

>>>> **Permanent vegetative buffer** - least-cost long term sediment control:

>>>> **LFH depth,** ft - buffer long term litter + fermented + humus depth.

>>>> **Slope %** - average slope of area used as buffer.

>>>> **Ground cover %** - total area % of LFH plus live ground cover.

Field Exercise

Select an activity site and make the measurements.

	LFH'	Slope%	GrndCover%
Ridge top			
South aspect upper slope			
North aspect upper slope			
East/west aspect upper slope			
South aspect lower slope			
North aspect lower slope			
East/west aspect lower slope			
Valley terrace materials			
Valley alluvials			

What differences in LFH depth do you notice?

>>>> **Expedient traps** - temporary measures; but they must last long enough to prevent overwhelming the natural buffer capacity and to meet revegetation standards on exposed sites.

>>>> **Time left, yr** - estimate current fill rate & remaining life.

>>>> **Kind of trap** - common temporary sediment control treatments
>>>> Ebsn Expedient sediment/debris basin.
>>>> Ecut Expedient in-channel trench or trough cut; no dam.
>>>> Efil Expedient filter/sorbent material fence.
>>>> Efur Expedient log & furrow sediment control.
>>>> Epit Expedient small sediment catch 'pit'.
>>>> Erow Expedient slash/brush wind row.

Common sediment traps are simple to build with the manpower and equipment normally expected on site. Try to use maintenance-free traps. For example, the normal installation of sidehill culverts can include a "pit" or hole at the outlet. The culvert installation is the same; there is just a hole down slope to catch the sediments. By the time the pit fills up, the erosion control efforts are supposed to be in place, and no pit maintenance is needed.

Field Exercise

Select an activity area, sketch the general storm runoff patterns, and design in a series of sediment traps that would eliminate sand size transport to the stream system.

>>>> **Stream receptor** - Sediment yields are tough to estimate. Start at the worst sediment source, track the eroded sand material through the buffer and temporary traps, then estimate what % made it to the stream.

>>>> Estimate **Sediment yield %** as that part deposited into the drainage feature. Since the receiving stream condition is also important, record what it is: perennial or intermittent, bog or wetland, overflow, ditch, or a swale.

<u>Field Exercise</u>

New sand deposits are fresh and bright, and are normally obvious on vegetated buffers and on the stream bottom. Since each geology and vegetation has its own characteristics, walk down a typical road and get a feel for normal sediment and buffer conditions. At each cross drain, look for the sand flow distance and whether there is a stream hit. The ratio of stream hits to the total number of cross drains sampled gives an estimate of sediment yield percent.

With this field experience, you can then estimate sediment yield percentages as a function of cross drains that are not adequately buffered and the extent to which the existing vegetation is likely to trap sediments.

If you see mass failures, take a close look at the buffer's effectiveness. Is the sediment yield near 100%?

What effect does different ground vegetation and ground roughness have on sand sediment flow distance?

Are the cross drains spaced to make effective use of the existing buffers?

Do you see any unstable areas that should be avoided with road construction?

>>>> If roads are a major source, **Sediment yield %** is the % of culverts & drains that lack an adequate buffer or flows direct into the stream network. If the **Vbfr** equation calculates a buffer length greater than the field condition, the buffer is too short. The **Vbfr** equation is based on data from paved, gravel, and dirt roads; it is applicable to most watershed development activities.

Vbfr= [10 + 10xRms + 100xGdp]/[Vcvr] where:

Vbfr = vegetated buffer needed to trap road & ditch erosion, ft.
Rms = (Road cross drain distance/1000) times (Road slope%)
Gdp = Ditch cutting or gullying in the ditch bottom; 0.1 ft.
Vcvr = Buffer Type (SEDFLOW) or = (plant + crs wood & herb litter, dec%).

Buffer Type & Condition			Vcvr Expect'd	& Range
S	Swale	undisturbed; no rills	0.4	0.3 - 0.5
E	Eroded	old rills common	0.2	0.1 - 0.3
D	Drops	holes, depressions	1.0	1.0
F	Fans	sidehill & ridge, no rills	(plant + crs wood & herb, dec%)	
L	LWD	windrows, slash, natrl falls	1.0	1.0
O	Open	trails, paths; not connected	0.4	0.3 - 0.7
W	Wander	cobbles, hummocks; no rills	1.0	1.0

There is a lot of information in this equation. Substantial care was used to create one that would be easy to remember and use -- so don't blow it off. It won't take long to understand and it will handle many common field situations without the need to run back to the office to find a computer.

Use the **Vbfr** equation to make simple field evaluations of engineering choices about road grades, water drain location, and ditch stability. Recall that <u>Rms</u> is a measure of erosive power acting on the road itself; <u>Gdp</u> is a measure of the resistance of road material to the erosive force. Both are translated into the vegetative buffer as distance required to filter sand materials out.

<u>Vcvr</u> is a measure of the buffer that combines vegetation cover (current or expected) and buffer shape; use the acrostic "SEDFLOW" to help remember:

S = Swales - gentle side slopes, relatively high density of live plant cover and/or woody debris, and no paths or rills that concentrate flow.

The Vcvr factor for Swales is 0.4 for most situations. It may be set at 0.3 for conditions that need extra room such as a narrow section of swale, or an expected increase in storm flow and sediment. It may be set at 0.5 for erosional conditions that will remain under control, or where storm flow will remain low regardless of the activities.

E = Eroded - existing rill or gully patterns that are healed and disconnected from the stream network. The Eroded condition is preemptive and sets the Vcvr value regardless of the vegetative density.

The 0.2 Vcvr factor for Eroded conditions will be used for most old rilled or downslope trailing conditions that do not connect with the stream system. Occasionally, a 0.1 is a better choice if rills dominate

the site or if the activity is expected to heavily compact the soils. Vcvr factors of 0.3 would be used if the rilled site has either slopes under 10% or has several cross cutting patterns that help spread flows.

D = Drops - holes or depressions in the ground surface that are NOT associated with existing flow patterns like Swales or mass failure features like slumps, or holes created by berms that can be breached.

F = Fans - unrilled and smooth sideslopes or ridges that allow sediment to "fan" or spread out. This is the typical buffer for which several buffer equations are designed. The Vcvr is a function of vegetative cover.

L = LWD; large woody debris (4">) oriented to create barriers must be in contact with the ground to be effective. Typical slash piles are not necessarily effective unless smaller material forms an immediate seal with the ground surface.

O = Open; where flow occurs along trails or paths that remain disconnected from the stream network.

Without the influence of trails, these sites would be Fans and the Vcvr based on ground cover; however, many areas have been worked over before by logging or livestock. The most common situation is 0.4; but sites such as old landings or concentration points for livestock or big game, would take a 0.3, and as patterns expand and trails become less important the factor occasionally gets as high as 0.7. The factor would never be higher than a Fan factor, but may be lower.

W = Wanders; flows that spread out amongst rocks or micro topography with rises greater than 2.5" (cobble material) tends to dissipate flow energy so sediments settle out in the buffer.

Road Ex. 1: 6% grade; 700 feet from last cross drain; 0.5 foot eroded ditch; and leads to a lodgepole pine buffer -- answer questions below:

What is Vbfr, if buffer type is	Swale	(70% LFH & plant)?	= 255'
" " " " " " "	Eroded	(70% LFH & plant)?	= 510'
" " " " " " "	Drops	(70% LFH & plant)?	= ~105'
" " " " " " "	Fans	(70% LFH & plant)?	= ~150'
" " " " " " "	LWD	(70% LFH & plant)?	= ~105'
" " " " " " "	Open	(70% LFH & plant)?	= ~150'
" " " " " " "	Wanders	(70% LFH & plant)?	= ~105'

Road Ex. 2: 3% grade; 900 feet from last cross drain; 0.4 foot eroded ditch; and leads to a grass and shrub buffer (80% LFH & plant).

If Vcvr is Eroded; what changes could you make to Vcvr to reduce buffer?

Considering both road and buffer conditions, what would be the least cost way to protect a stream 90' away from the road?

Several things to emphasize about Vcvr factors:

-- First, small scale roughness features that keep flows spread out and trap sediment tend to be more affected by management activity than general buffer shape. Small features are indexed using live plant cover, woody debris, and coarse herbaceous litter. Small or fine litter is not counted unless it is tied down and can not float away during high intensity storms.

-- Second, Vcvr factors are never greater than 1. This means that the buffer can not be less than that calculated for the engineering factors (10 + 10*Rms + 100*Gdp) themselves. Efforts such as energy dissipators or drop chutes are important erosion control efforts but they do not lessen the buffer needed for long term protection of stream health. Two typical road maintenance procedures, "pulling the ditch" and resurfacing with new gravels, are major and constant sediment sources that are most economically controlled by vegetative buffers.

-- Third, there is a hierarchy. The rule is to use the Vcvr with the lowest value. In so doing, the control is based on the most vulnerable condition -- current or expected in the future. For example, a current buffer with a Vcvr = 1 that is likely to be damaged by erosion during project activity should be evaluated using a Vcvr = 0.2 for the expected Eroded condition.

-- Fourth, the risk that a buffer might become saturated and fail increases with potential for mass failure. Current field experience suggests that buffer slopes over 30% in geologies subject to earthflows, or over 55% in geologies subject to debris avalanches are high enough risk to warrant a buffer slope stability analysis for saturated conditions. This may result in a road drainage pattern that reduces total runoff volume contributed to any particular buffer or, perhaps, complete road relocation.

-- Fifth, the risk that a buffer might become eroded increases as buffer slope increases. This is particularly true for soils with low infiltration rates or soils that lack internal cohesiveness. There is also a point where deep litter layers will float into a downhill cascade. Current field experience suggests that buffer slopes over 40% combined with Rms's greater than 5 are high risk.

Field Exercise

Pick a 2 lane gravel road segment and calculate the vegetative buffer distance.
Name: Grade%: Drain dist: Rills:

Buffer type: Cover%: Vbfr:

Pick a single lane road segment and calculate the vegetative buffer distance.
Name: Grade%: Drain dist: Rills:

Buffer type: Cover%: Vbfr:

Pick a typical woods road segment and calculate the vegetative buffer distance.
Name: Grade%: Drain dist: Rills:

Buffer type: Cover%: Vbfr:

Thalweg Depths

Training for thalweg depth (T-Depth) measurements and evaluation includes these commitments on the part of the trainee:

1. learn the definitions and how they apply to stream geometry;
2. study photographs of different bankfull stage conditions;
3. spend time with a trainer looking at local streams;
4. work several streams to perfect techniques; and
5. call for a 2nd visit from the trainer for a consistency check.

Background Key Ideas

One major impact to diversity and production is the loss of pool depth and the loss of macroinvertebrate production. Changes in either one or both parameters are suitable measures for a variety of land use impacts including logging, road construction, canals, mining, and grazing.

The Clean Water Act supports the orderly development of natural resources and recognizes that there will be some impact. The key is to keep the impact confined to a reasonable area and check on spill-over effects that are not covered by permit.

Field Manual Instruction

>>>> Thalweg Depth (by tally)

>>>> This is the heart of **T-Walk**. The purpose is to characterize the thalweg depth and evaluate substrate conditions that influence fish food production.

>>>> Location is important. **T-Walk** must be done close enough to address stream impact, but not so close that sacrifice (wipe-out) areas are included. For example, leave 200' below construction sites before starting a T-Walk reach.

The best locations avoid the direct construction impact areas and include some weaklinks to anticipate impending damage. Typical weaklinks include short radius meanders, raw banks, steep bank slopes, highly erosive soils, lack of vegetative protection, mass failures, or combinations of several factors.

Select a good stream reach for monitoring and sketch map the suitable weaklinks. What factors did you key on?

>>>> Work along the reach at equally spaced distances. Surveys with 30, 50, or 100 points are common. Select the number of points that will pick up the variety in pool depths. For shallow streams (<2') with regular features, 30 points (22'±) provide minimum statistical control. For deeper streams or those with pool-riffle or step-pool sequences, 50 points (13'±) are needed to provide minimum statistical control (2/3 chance) and 100 points (7'±) provide substantially better statistical control (9/10 chance).

At each point, check substrate size, sand infill, and vegetation within the low flow channel; then measure the deepest thalweg depth (1/10'). Look at the stream bottom to identify excess sand moving into the system during the early stages of deposition. Most obvious will be small sand waves or dunes building behind larger rocks, or more than a 10% covering of larger rock surfaces. Current experience suggests that you ought to do at least 50, or better still, 100 points on most mountain streams.

When streams are very small and there is no need to go the full 1/8 mile, do at least 210' (30 points x 7' spacing), or 2 full meanders, or 20 times the channel width, whichever is greater. The 7' spacing is usually satisfactory.

Sometimes stream reaches of more than 1/8 mile are needed to provide information about channel features or to cover 2 full meanders. Feel free to make the longer survey, but make sure you record the length and the spacing between the points. There are several options; for example, if the reach is 1000', then 50 points at 20' or 100 points at 10' or 142 points at 7' are all choices.

>>>> **Thalweg Depths** - low water surface; tally depth by category.

>>>> Qbf to water surface 0.1' - provides year to year stage reference. If Qbf is not used, note precisely what was & location.

Select as well defined bankfull marks as you can that will also be easy to locate next year; make a sketch map of how to locate it. If possible, use relatively quiet water such as near pools or just upstream from riffles and avoid areas of high turbulence and dancing waters. Measure from the bankfull stage to the existing water surface and record to the nearest 0.1'.

If you can not find bankfull stage, make the measure from some prominent point like a boulder or concrete structure bridge that can be described and relocated.

Bankfull stage is an important field indicator that remains relatively constant; the following photos are examples of what to look for.

How To Review the Photos Plates Q1 and Q2 for bankfull stage.

1. The photo number consists of year, month, day, and a frame sequence. Photos are noted as upper (U), lower (L), left (L), center (C), or right (R).

2. Bankfull discharge is the primary channel forming flow; and, because of its frequency, leaves durable and consistent marks of the level or stage of these flows. These bankfull marks are most apparent in stable stream reaches subjected to natural flow conditions; but, since they the result of physical processes, they can be located for many unstable or altered stream flow conditions as well.

3. The point is that they are durable and can be used from year to year.

4. Plate Q1 UL and Q1 UR are different sections of the same stream.

Q1 UL shows bankfull stage with a flag line. It is about 0.5' below top of bank. As you reach through the overhanging grass and lift, you will find a general line below which grass stems are not growing. There may be other indicators such as a slight shelf or ledge, an undercut, or a slope break.

Q1 UR shows bankfull stage just at the top of the grass root crown and brush root crown (far L). Note the floating grass vegetation.

5. Q1 LL (3C) shows an exposed root crown. Bankfull stage is marked by the start of brush stem growth, a layer of old litter, and a pronounced slope break. Tree saplings will also be above bankfull stage (left end of survey rod).

6. Q1 LR (3F) shows bankfull stage as slope break and start of brush growth and top of root crown. Just up from Pandora, bankfull stage is also a break in texture from large rock to soil material and litter.

7. Q2 UL shows bankfull stage at top of brush root crown and a slope break.

8. Q2 UC shows the stain from frequent occurrence of bankfull stage on stable rock surfaces. Sometimes lichens or moss will also show a bankfull stage line.

9. Q2 UR shows a ledge or bench created at bankfull stage. Use your hand to feel for small bench cuts under heavy grass line and confirm with top of root crown and slope break.

10. Q2 LL. Several indicators of bankfull stage from a larger view include the grass-line, brush growth, bare ground, and slope breaks. For meandering streams that have well developed point bars, the top is an indication of bankfull stage (A). The obvious change in particle size distribution is common on streams with enough sediment transport to settle sands out on the downstream edge (B). And slope breaks are a common feature (C).

11. Q2 LR shows a channel undergoing extensive adjustment due to a fire followed by heavy flooding and sedimentation. The flow is at bankfull stage; and is just at the top of brush root crowns. The mid-channel bars are recent deposits and contribute to the accelerated bank erosion.

>>>> **Thalweg velocity '/s** - if hiQ use 0.8x float vel or 8*sqrt(vel head).

Variable stream flow and corresponding stream width, depth, and velocity profiles influence sediment transport, channel shape, bar deposition, bank cutting, and the distribution of stream bed materials. All of which have a major influence on the structure of plant and animal aquatic communities.

To use floats, pace or measure a distance along the channel bank that is about 10 times the channel width in the straightest part of the reach; and at least 100 feet. Throw 5 or 6 sticks into the upstream end of the main thalweg velocity current and start counting the seconds. Keep your eye on the floats and move downstream. Record the time for each piece that stayed in the thalweg current and crossed the end line. Average the times and calculate surface velocity (distance'/time, sec). If the readings are for low flows or those below, say 1/4 bankfull, then just record the average without making any correction. If the flows are higher than 1/4 bankfull or tend to deep and laminar then multiply by 0.8 (rough bed and 0.9 for smooth bed) to obtain thalweg velocity, '/s.

<u>Review Photo Sheets Q1 and Q2</u>

What correction, if any, would you use if the stream looked like:

Q1 UL	0.8	0.9	none	|	Q1 UR	0.8	0.9	none
Q1 LL	0.8	0.9	none	|	Q1 LR	0.8	0.9	none
Q2 UL	0.8	0.9	none	|	Q2 UC	0.8	0.9	none
Q2 LL	0.8	0.9	none	|	Q2 LR	0.8	0.9	none

<u>Field Exercise</u>:

Select a straight reach, pace off about 100'. At the upstream end, throw 5 or 6 pieces of wood into the thalweg flow, and start counting seconds. How long does it take for the pieces to travel the 100'? Keep individual times as they float by the cut-off. Average the readings. If the flow is less than 0.5'$\pm$ deep, just record the average; otherwise, multiply by 0.8 to get the average thalweg velocity. The estimate is approximate so don't get carried away with the decimal places.

\>>>> **Max & Min depth 0.1 ft** - record maximum & minimum of all points.

\>>>> **Pool, Veg, Shore, & Jam** - dot tally for use in the Diversity Screen.

\>>>> **Depth Categories** - at each point measure the thalweg (deepest) and tally the appropriate depth category. At end, convert tally into <=% category exceedence values and plot using max & mins as graph limits.

As you take depth for the categories, keep a cuff record of possible maximums and minimums as you go along, then fill in the form when done. Face upstream and stand far enough to the side or behind to avoid affecting the flow level.

Calibrate distance in terms of your reach with the T-Stick. Upon occasion you may need to move the T-Stick a little from side to side to find the deepest point. Also at each point, take a moment to dot tally the presence of pools, stream bank vegetation (may be 0, 1, or 2 for both sides), stable shores (may be 0, 1, or 2 for both sides), and number of jams. This will save you an extra trip along the reach to calculate these percentages for the diversity screen.

Exercise .

Convert the following data to the form; calculate % exceedence values and plot on 10x10 paper: bank distance of 100' with float times of 30, 41, 34, 39, and 47 seconds. Qbf to water surface = 0.8';

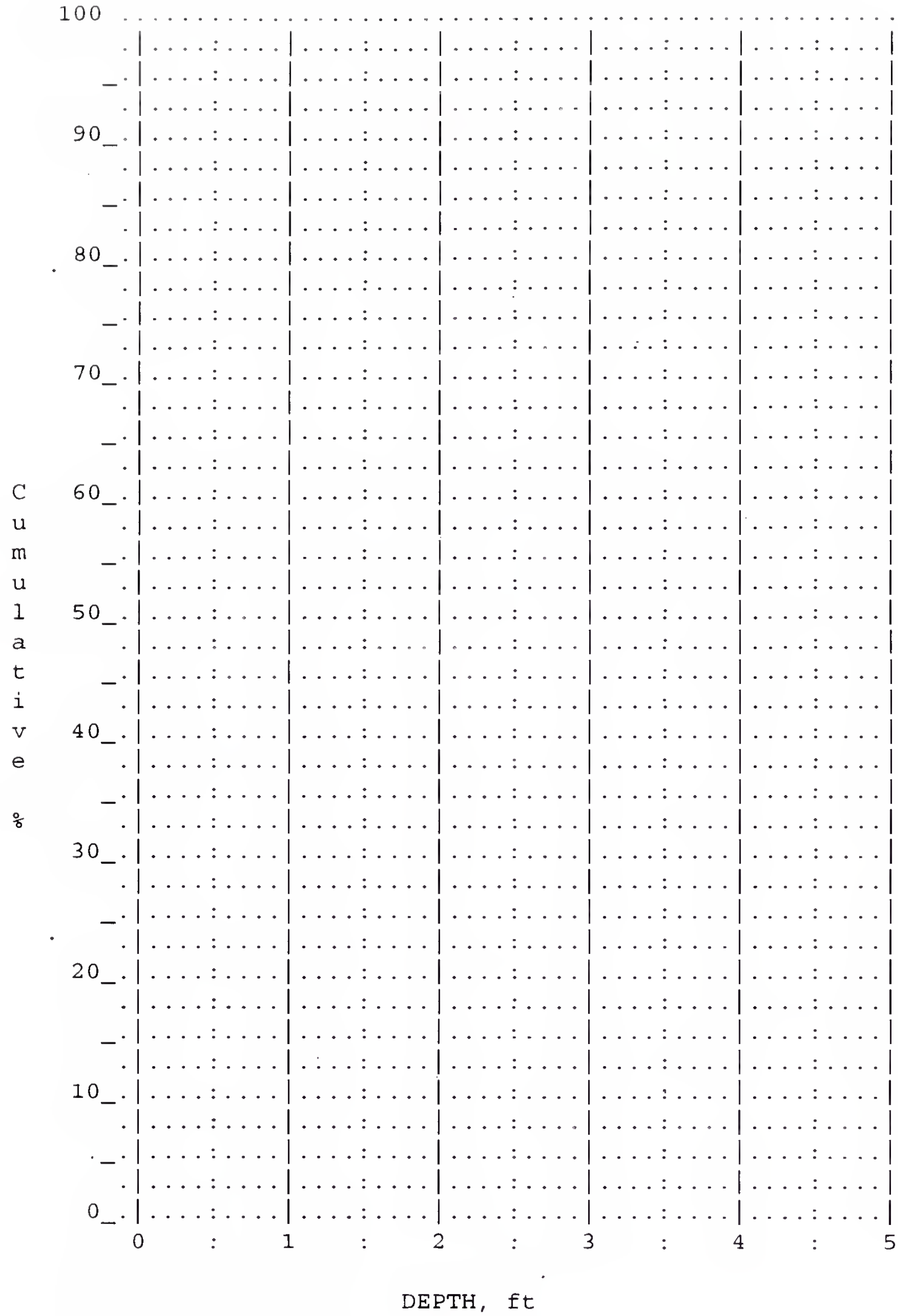
0.3	0.8	1.2	1.5	1.1	0.8	0.4	0.9	1.5	2.6
1.1	2.3	2.9	3.4	2.6	1.0	0.4	1.5	1.8	1.0
0.6	1.9	3.0	1.5	1.9	2.0	2.1	0.9	2.7	2.0

THALWEG DEPTH (0.1' by tally)

Qbf to wtr: surface :	Tvel '/s	Max dp'	Min dp'

0.0 - <0.5	1.8 - <2.0	3.0 - <3.2	P o o
0.5 - <1.0	2.0 - <2.2	3.2 - <3.4	l______
1.0 - <1.2	2.2 - <2.4	3.4 - <3.6	V e g______
1.2 - <1.4	2.4 - <2.6	3.6 - <4.0	S h o
1.4 - <1.6	2.6 - <2.8	4.0 - <5.0	r______
1.6 - <1.8	2.8 - <3.0	5.0 - over	J a m

Thalweg Depth Profiles



Tarzwell Substrate Ratios

Training for substrate evaluation and stream productivity includes these commitments on the part of the trainee:

1. study sizes of rock material common to substrates
2. study photographs of different substrate conditions;
3. spend time with a trainer looking at local streams;
4. work several streams to perfect techniques; and
5. call for a 2nd visit from the trainer for a consistency check.

Particle Sizes

Before we start Tarzwell, you need a working knowledge on rock sizes or "pebbles" and the standards by which classes are named. T-Walk uses the double scale adopted by the American Geophysical Union in 1947. The dimension used to place a pebble into a particular class is the intermediate axis. The intermediate axis is also the diameter of a hole that just barely allows the pebble to pass through. For example, a long flat rock that is 8 x 16 x 90mm would be classified based on the 16mm and would be called "coarse gravel."

What would you call these?
(all numbers are mm)

1 6 4 (put in 4 - 8 class)

22 44 55

2 4 12

2 2 2

floury, no grit (silt & clay)

35 23 128

350 45 87

200 120 480

1 1 1

===================

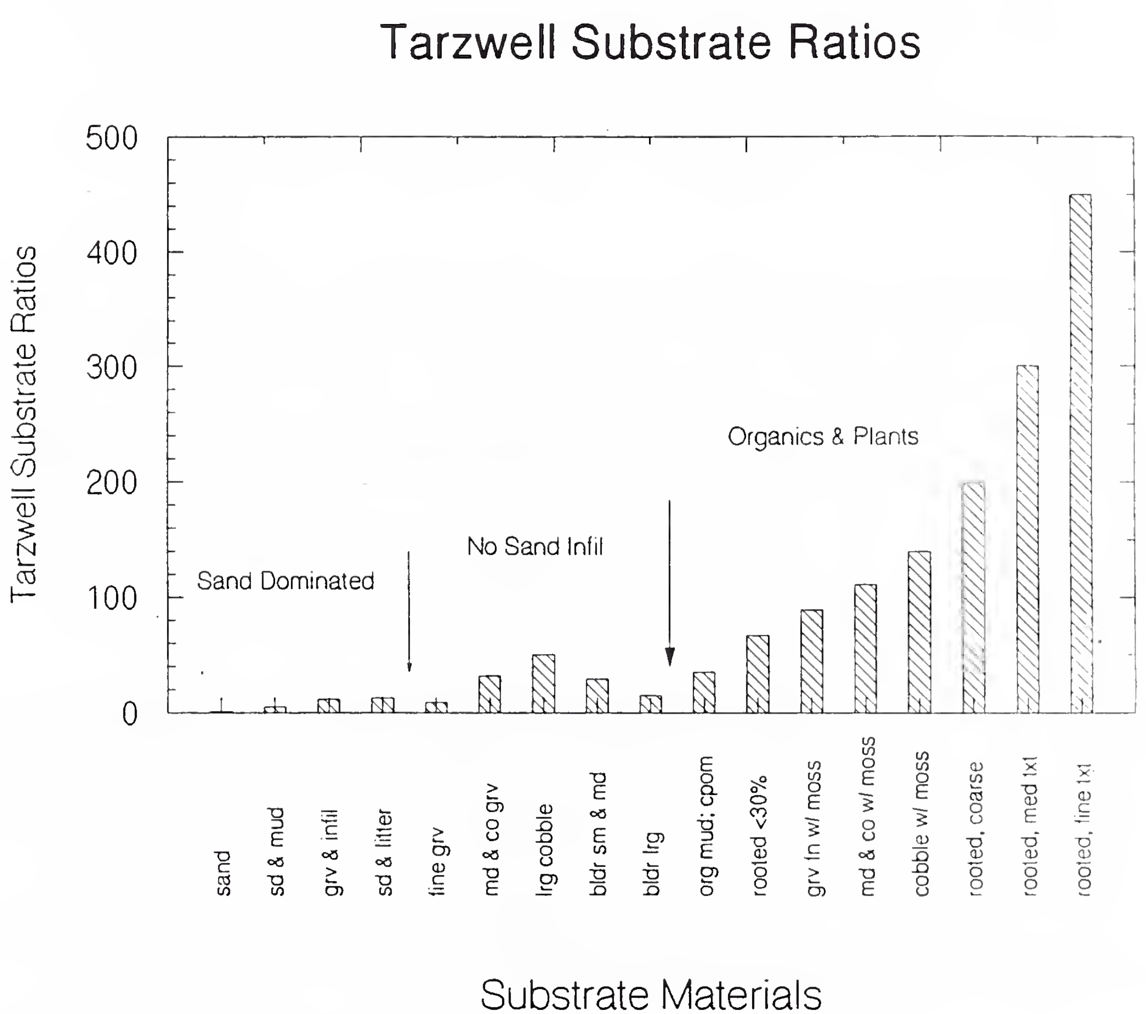
From the box of "rocks"...

Class	Size, mm
Fines Si&Cl	<0.062
Sand	0.062- 2
Gravel v.fine	2- 4
Gravel fine	4- 8 - 0.3"
Gravel med	8- 16 - 0.6"
Gravel coarse	16- 32 - 1.3"
Gravel v.coars	32- 64 - 2.5"
Cobble sm	64- 128 2.5- 5"
Cobble lg	128- 256 5"- 10"
Boulder small	256- 512 10"- 20"
Boulder md	512-1024 20"- 40"
Boulder large	1024-2048 40"- 80"
Boulder v.lg	2048-4096 80" 160"
Bedrock	4096 - + 160" & >

Background Key Ideas

Biological integrity includes production. The most generic concept is ecological carrying capacity; in the context of T-Walk the best choice appears to be the Tarzwell Substrate Ratio ... as a measure of macroinvertebrate habitat.

During the 1930's, the Michigan Emergency Conservation Workers agency did extensive in-stream structure work on 6 rivers. Over a 5 year period, Dr. Tarzwell analyzed 447, 2' by 2', bottom samples taken from substrates that represented typical stream conditions before as well as after restoration efforts. Part of his results included summaries of fish food production ratios for different substrates. .... The graph summaries his results:



>>>> Tarzwell Substrate Ratio (by tally)

>>>> Sedimentation of coarse substrates by sand produces significant detrimental effects on salmonid resources by affecting spawning areas and by reducing primary and secondary production. **Tarzwell Substrate Ratio** is a dimensionless measure of macroinvertebrates produced on different substrates indexed to sand as the least productive. The tally uses 3 groups: sand dominated substrates, rock dominated substrates without excess sand, and substrates influenced by vegetation or organic matter. Excess sand shows as waves behind larger rock, as dunes or ripples, as embedded gravel, or as buried plants. Sand infill begins when >10% of larger rock surface or perimeter is obscured.

>>>> **Tarzwell Substrate Ratio** - Near the depth tally spot, visually match the substrate to the TSR categories. If you can't see, try a snooper. Individual rocks sometimes indicates embedded condition by color change or animals just only along the fringe. When tally is complete, convert dot tally into % for each category, multiply category TSR by its %, and total. The total is an average Tarzwell Substrate Ratio for the reach.

By identifying a shift toward sand dominated substrates, the T-Walk rationale infers that there is a substantial decrease in production. For example, adding excess sand to a normal cobble substrate with a Tarzwell Substrate Ratio of 32 will reduce the ratio to 12; this is a drop of about 2/3rds in productivity.

In the field, the challenge is to use something like a "snooper" to see the stream bottom and visually match what you see with the substrate descriptions used on the Tarzwell Substrate Ratio form. Review each category description and the associated Tarzwell Substrate Ratio (TSR). If the form shows more than one substrate condition with the same TSR, treat each condition as independent. For example, sand infill with medium or coarse gravel, or small cobble, or large cobble, or boulder conditions all have the same TSR = 12.

Note the 3 basic groups of substrates: those dominated by sand, those by rock, and those by vegetation. The gravels, cobbles, and boulders are defined by size in millimeters with adjectives: fine gravels (<8mm), medium gravels (8- <16mm), coarse gravels (16- <64mm), small cobbles (64- <128mm), large cobbles (128- <256mm), and boulders (256mm & >). The vegetation component includes the higher plants but not algae. Algae growth tends to be erratic and opportunistic.

There are two categories: inorganic muds tabulated with sands, ("sands w/ inorg muds") and those mainly "organic muds and muck". Inorganic muds have a smooth or floury feel and are mainly silt and clay.

In summary, a field survey will consist of 30 to 100 points along the thalweg, for which you will visually match the substrate condition at each point with a Tarzwell Substrate Ratio category, and mark the category with a dot tally. Be sure to choose reference conditions with care, so the determination is a fair comparison with regard to substrate materials and instream vegetation.

How To Review the Photos

Review Plates T1 - T9. Photo positions are noted as Upper or Lower, Left or Right; "UL" would be the upper left photo. On a given photo, sections may be further located as "Top, Middle, Bottom" (T M B); and/or "Left, Center, and Right" (L C R).

Often a single photo will show several TSR conditions; this is done to provide a variety and keep the costs down. But don't get confused; in a real survey, you will stop about every 7' (or as selected) and take a square foot TSR reading.

Read the photo brief and match what you see with the TSR categories. Take time to look close, then make a dot tally of the different TSR's that you see.

T1 UL Natural condition in a high sediment yield area of Absaroka volcanics. The stream gradient is high enough to prevent deposition and the boulder and cobble substrate does not show sand infill or plant materials. The TSR = 50.

T1 UR Condition is influenced by a nearly flat stream gradient with clay, silt, and organic materials on the bottom (take my word for it). For bottom center, choose the category for "organic muds and muck" (TSR=35). At middle center with the cattails, "rooted >30%, coarse texture" (TSR=200) would be a good choice.

T1 LL Condition is mainly coarse gravels and small cobbles with no sand infill. Ignore the algae: there is no associated TSR and algae growth cycles are not dependent on substrate or sand conditions. TSR = 32.

T1 LR Low gradient stream running through forest duff and litter. The bottom is leafy material with organic muds and muck (TSR=35); and areas of coarse plant material (CPOM) which includes branches, twigs, and leaves (TSR = 35).

T2 UL Boulders mainly surrounded by fine gravels, but no sand infill. This is a judgement call, but productivity is controlled by the fine gravels (TSR = 9); the boulder arrangement does not create large nooks and crannies.

T2 UR Small cobble and coarse gravels without sand infill would ordinarily have a TSR = 32. However, the heavy sand deposition creates a sand infill and drops the TSR down to 12. The high chroma is almost always a sign of new material entering the stream system; in this case, from extensive road erosion.

T2 LL Small cobble with infill, TSR = 12. The deposition, a combination of fine sands and inorganic muds, is heavy enough to smother and infill many cobble spaces; but it is not heavy enough to call it "sands with inorg mud" (TSR=5).

T2 LR The organic debris at BC and BR would be counted as coarse particulate material (CPOM TSR = 35). The plunge pool is clear of plant material; TSR = 32.

T3 UL Mainly coarse gravels without a sand infill; TSR = 32. There is sand in the system, but not enough for sand infill condition. Note the dull chroma.

T3 UR The TSR = 32 in the mid & top center with coarse gravels and no sand infill. Moss at mid-left and along the bottom are given a TSR = 111.

T3 LL Look close; the bed is a composite of gravels all more or less the same medium gravels with no sand infill. TSR = 32.

T3 LR The plant cover is valuable cover and generally would be classed as "less than 30% rooted cover" (TSR=67). The gravels are free of excess sand: TSR = 32.

T4 UL Coarse gravels and small cobbles show sand infill with new bright chroma; some older sand infill and some original gravels that are buried. TSR = 12.

T4 UR MR Cobbles are almost buried in sand (TSR = 1); TC & TR are cobbles buried in fine gravels and sand (TSR = 5). At MC & BC, note the perimeters of individual rocks and the associated sand drifting over their edges (TSR = 12).

T4 LL Left of the log the sand infills the coarse gravel and small cobble substrate with a TSR = 12. On the right side of the log, several areas are drifted sands with a TSR = 1; the gravels are buried.

T4 LR Vegetation with a medium texture (Coontail) would be counted TSR = 300. Note the shift as sedimentation encroaches on the vegetation resulting in sand infill (TSR = 13). Between the 2 nails, the condition is gravel bed with sand infill, with a trend toward being buried. The high chroma material suggests recent deposits (in this case, deposits are within the last 2 years).

T5 UL This stream is recovering from logging road construction in the 1960's. The high chroma sand indicates that road erosion is continuing to impact the stream. The TSR = 12 sand infill shows best along the bottom where they have accumulated; however the top-left shows less sand and would be assigned TSR = 32 even though sand is obvious. For a stream that is recovering or just starting to be impacted, it is not uncommon to have both conditions expressed.

T5 UR Sands have just about buried the gravels. Ordinarily this stream would have a TSR = 32. Now TSR = 1 over much of the channel sand surface.

T5 LL The high sand chroma indicates that sand damage is continuing from the logging roads built during the 1960's. Based on nearby unimpacted streams, the moss coats the under water rock system (TSR = 111); which means that the resulting sand and fine gravels (TSR = 5) reflects a 95% loss in productivity.

T5 LR Mainly the result of acid mine drainage (how can you tell?) with a resulting TSR = 0 because of chemical problems. The rocks are also coated with a fine grain precipitate.

T6 UL The black material is moss. Sand and fine gravel (TSR = 5) have buried the original moss-covered gravel and cobble bottom (TSR = 111). Road erosion generates new (high chroma) sand and fine gravel every time it rains.

T6 UR Original material was coarse gravel and small cobble with no plants and a TSR = 32. Road erosion, starting in the 1940's continues to create fresh sand infill. Sand and mud predominates (TSR = 5); would TR & BR be as high as 12?

T6 LL Original gravels (TSR = 32) are buried in sand and fine gravel (TSR = 5).

T6 LR Condition is beyond "infill" and well on its way to being buried; the rocks no longer provide habitat. However, deposition is fine sand and inorganic muds (TSR=5) and would likely blow clean(er) if there was a high flow. Site recovery would be rapid if watershed conditions were improved.

T7 UL This condition is naturally generated. Sand and mud areas have a TSR=5; gravel areas with sand infill have TSR = 12. The geology produces grey material which makes seeing the difference in chroma between new and old difficult.

T7 UR The sands have just started to take out the coontail and may eventually bury the vegetation. But for now, TSR = 13 for "plant with sand infill" would be a good choice for the top of the picture. The coontail along the picture bottom is still free of the sand and the TSR = 300 for "medium texture, rooted".

T7 LL The original gravels (TSR = 32) have been buried in sand, silt, and clay, and fine gravels (TSR = 5).

T7 LR Three conditions show the progression of sand infill. Left side is now clean sand (TSR = 1), that meets an edge with the old residual gravel (TSR = 12 for gravel with sand infill), and finally sand encroachment into a gravel moss complex in the upper right corner (TSR = 111). Bright chroma shows what?

T8 UL & LL are the same stream. The bed has large cobble but is mainly small cobble. Would you agree there is no sand infill? What is the TSR?

For UL, what is the stream gradient? Would you agree that this stream would be vulnerable to sedimentation damage? Once a sand infill occurs there is little stream energy available to turn the rocks over and flush the sand out.

T8 UR & LR are the same stream. The bed has small cobble but is mainly medium and coarse gravel. Do you see sand infill? What is the TSR?

For UR, what is the stream gradient? Would you agree that this stream would be vulnerable to sedimentation damage? Once a sand infill occurs there is little stream energy available to turn the rocks over and flush the sand out.

T9 UL & LL are the same stream. The bed has some large cobble but is mainly small cobble and assorted gravels. Would you consider the sand on the right side to be sand infill? What is the TSR?

Now look at UL. Is this stream vulnerable to sedimentation damage? Why?

T9 UR & LR are the same stream. The bed has some small cobble but is mainly medium and coarse gravel. Is there enough sand and fine gravel to influence the TSR? What is the TSR?

Now look at UR. Is this stream vulnerable to sedimentation damage? Would you expect the sand and fine gravels to be natural or from a past impact?

>>>> **Channel Materials** - mark d50 & d84 of surface materials (i.e. Pebble Count); note bimodal distributions. Be specific but without forcing the data.

The classification, measurement, and analysis of particle size distributions used by T-Walk is based on the method developed in 1954 by Gordon Wolman. The Wolman Pebble Count is a systematic sample of 100 rocks taken from a set pattern in streams shallow enough to wade. The pattern depends on the objective of the survey. The most common is to generate a composite data set for the reach by equally sampling both riffles and pools; but many surveys concentrate on particular features such just riffles or just bar formations.

The pattern that you select for a pebble count depends on the objectives. The typical pebble count is done along a series of transects laid perpendicular to the flow and spaced to equally sample pool and riffle sections. Another pattern that works well for T-Walk is to run the transect on the diagonal. The sampling starts at bankfull on one side, and with equal spacing, proceeds on a diagonal (zigzag) to bankfull on the otherside.

The drawings below suggest some patterns for particular reasons.

```
      riffle   pool    riffle   pool    riffle   pool   riffle   pool  riffle
Qbf> ---o--------o--------o-------o--------o-------o-------o-------o---------
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
       ~~|~~~    |      ~~~|~~    |      ~~~|~~    |     ~~~|~~    |   ~~~~~~
Qbf> ---o--------o--------o-------o--------o-------o-------o-------o---------
```

Perpendicular -- samples 4 each in pools and riffles.

```
Qbf> -------o---------------o---------------o---------------o---------------
      ~~~~~~/ \          ~~~~~/ \          ~~~~/~\          ~~~~/~\        ~~~~~~
      ~~~~~/   \         ~~~~/~  \         ~~~/~~ \         ~~~/~~ \       ~~~~~~
      ~~~~/~    \        ~~~/~~   \        ~~/~~~  \        ~~/~~~  \      ~~~~~~
      ~~~/~~     \       ~~/~~~    \       ~/~~~~   \       ~/~~~~   \     ~~~~~~
      ~~/~~~      \      ~/~~~~     \      /~~~~~    \      /~~~~~    \    ~~~~~~
      ~/~~~~       \     /~~~~~      \    /~~~~~~     \    /~~~~~~     \   ~~~~~~
      /~~~~~        \   /~~~~~~       \  / ~~~~~~      \  / ~~~~~~      \  ~~~~~~
Qbf> o---------------o---------------o---------------o---------------o-------
```

Diagonal -- from bankfull to bankfull for specified distance.

Exercise.

1) The dimension to be measured is the intermediate axis that controls the size of the sieve hole (round) the pebble will just pass. Draw in a set of "paper" rocks that corresponds to the dimension arrow and the intermediate axis. Hint: the thickness of the paper is not the intermediate axis.

--> <-- --> <-- --> <--

2) For the following data, make a cumulative % v. size graph.
1st: sum categories; make a running tot; convert to percent.
2nd: plot cumulative % at high end of category range.

PEBBLE COUNT for: ARB. & CAPRI.

Class	Size, mm	Tally	Tot/%Cum
Fines Si&Cl	<0.062	::	
Sand	0.062- 2	[]	
Gravel v.fine	2- 4		
Gravel fine	4- 8 - 0.3"		
Gravel med	8- 16 - 0.6"	[X] .	
Gravel coarse	16- 32 - 1.3"	[X] [X] :	
Gravel v.coars	32- 64 - 2.5"	[X] [X] [X] ::	
Cobble sm	64- 128 2.5- 5"	[X] ::	
Cobble lg	128- 256 5"- 10"	::	
Bldr sm	256- 512 10"- 20"	:.	
Bldr md	512-1024 20"- 40"		
Bldr lg	1024-2048 40"- 80"		
Bldr v.lg	2048-4096 80" 160"		
Bedrock	4096 - + 160" & >		

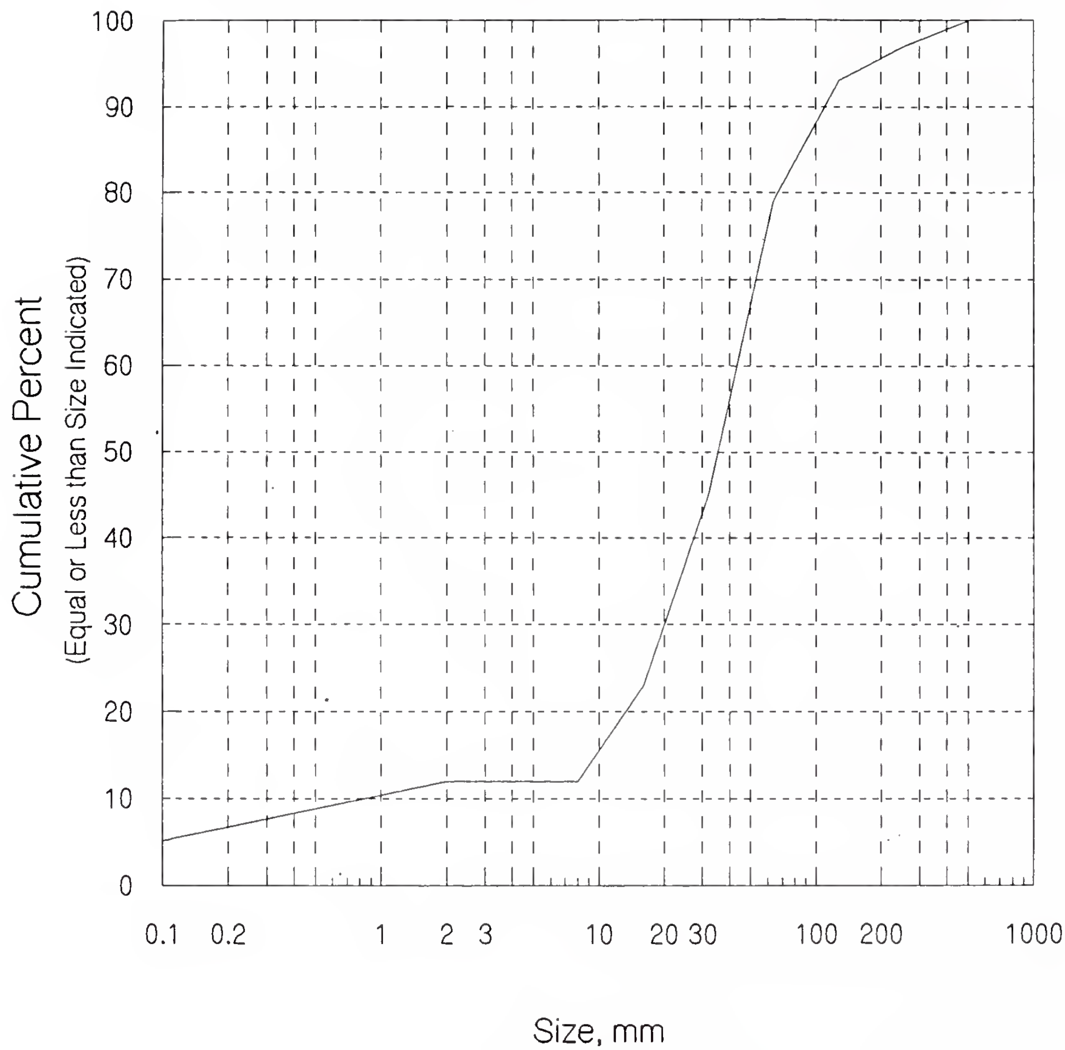
Field Exercise

1) Select a reach; do a zigzag Pebble Count (form in pocket).

2) Prepare a cumulative % v. size (log scale) graph. Mark d50 and d84.

Particle Size Distribution

(Arbitrary & Capricious Creek. 5/1/1994)



>>>> Remove the top layer to check subsurface materials; note any unusual layers or size combinations.

>>>> Look for d84 for the bankland rock composition; slope stability depends on the structural interlock provided by larger sizes. Find high flow stage (Qbf); note d84 of weakest layer or plane between different sedimentary beds. Bank strength is an integrated feature: note cohesive matrix (yes/no); non-cohesive or slip lens; rooting at Qbf (if yes, mark grass, shrub, or trees); pipe or side fracture; and large woody debris (lwd = 4" >).

Channel stability is attained when the bed and bank material forming the channel boundary effectively resists the erosive energy of all stages of flow and the channel remains essentially unchanged. For T-Walk, the stability relationship is best expressed as allowable velocity for particular channel conditions.

<u>How to Review the Photos:</u>

Plate B1 - shows some typical situations where bed and bank materials have major influences on stream characteristics.

B1 UL (#05E) stream stability is created by the number and placement of the boulders (d84 is boulder). Vegetative bank support is somewhat incidental.

B1 UR (1061F3) shows a gravel stream system with signs of recent deposition and bank cutting. The medium gravel d84 is not stable; vegetation is critical to stream stability.

B1 LL (910515.26) is a completely natural system created in volcanic rock types that are fine grained and very erodable. The d84 material on the left side is mainly cobble, but generally the system d84 is mid range gravel with lots of sand size and smaller material. Vegetative support will be the main avenue of bank stability -- just as soon as some develops.

B1 LR (920501.15) is an unusually clear example of a bedrock channel. The bank material is a thin layer of alluvial material with a d84 of cobble. Vegetation provides some extra strength to a very stable system.

Plate B2 - shows some typical stream bank materials (& one great smile).

B2 UL shows massive, unconsolidated, sandy material with a d84 of small gravel. Vegetative strength is minor:

B2 UC shows that the d84 support is large angular cobble and boulder material. The channel is typical for steep streams in geologies with hard rocktypes.

B2 UR shows highly organic bank material as mainly a mixture of sands (minor silt and clay) from upstream and organics from the aspen stand. The d84 is no greater than small gravel, but bank strength relies on vegetation.

B2 LL shows bankfull flow level (pole) with d84 cobble material typical of coarse gravel and cobble streams. Vegetation provides added bank strength.

B2 LR shows bankfull flow level (pole) with d84 small boulders typical of cobble and boulder streams. However, the boulder material comes as part of colluvial processes and has a greater range of soil material than, say, the large boulders in photo B1 UL. Vegetation adds some bank support.

Plate B3 - shows some effects from geomorphic processes on bank materials.

B3 UL shows coarsening of bank materials from gravity and the wash out of finer materials. The material is sand and gravel with d84 of small cobble.

B3 UC shows glacial material that has not been sorted and converted into stream bank edge. Even though the large boulder material is visually dominant, it is not providing the support to this system. Looking at the photos upper 2/3rds, the interlocking d84 is medium size gravel.

B3 UR shows alluvial material with several layers. The top red sand has a d84 of sand. The buff layer is sand and gravel (d84 small gravel). Next layer is the weakest and is a non-cohesive mixture of sands and silts (d84 sand). The next layer is medium and coarse gravel layer (d84 gravel).

B3 LL shows alluvial material that is mostly sand (d84 sand). At one time the channel was about 4' higher than now and alive with beaver activity. Past down cutting is probably related to extensive grazing, loss of beaver, and loss of willows. The current situation is aggravated by reservoir operations that periodically "flush" the system.

Project work to re-establish this as a fisheries, has concentrated on bank stability at the toe to help willow plantings get established again. The sands and small gravels (d84 small gravel) are very unstable. Vegetation, coupled with a change in reservoir operations, appears to be the only feasible way to provide the bank stability.

B3 LR shows stream character as created by presence of large woody debris. The rock material includes sands and gravels (d84 medium gravels).

Plate B4 shows some common impacts on streams from the intrusion of roads.

B4 UL shows a canyon with rock outcrops at stream level (left side of photo). All of the vast amount of road construction has generated side cast material that narrows up the channel. Except in local spots, the channel material remains resistant to the deeper and faster flow and there is no obvious stream widening.

B4 UR shows a typical effect of a road fill crowding in on a stream system. Whenever road construction places large amounts of fill and side cast material into the stream, the stream course narrows and the hydraulic forces are re-arranged. If both sides of the stream course are stable under the new hydraulic regime, then the stream is merely deeper or faster. However, if either side of the narrowed stream segment is unstable under the new flows, then adjustment take place. In this case, the river is re-gaining it's width by eroding the stream banks on the far side.

B4 LL (910702.18) shows yet another long term problem in equilibrium. In this case, the channel cut was made 20 years ago. Note that the toe of the

cut is primarily stable with boulder material (d84 boulder). But the slope itself is not stable, and it will take a long time for the upper slope to unravel enough to reach an angle of repose. Note the condition of the vegetation along the upper edges. The typical sequence is for the exposed vegetation to die, followed by collapse of the edge, and a repeat cycle of new vegetation exposed. How long do you think it will take to stabilize?

B4 LR (890810.20) shows a very recent problem in stability caused be a bridge installation that narrows the stream -- using fine material to do so. Note the difference in size of bank material on the far side. If the material on one bank is substantially larger, where do you think the stream bank will finally stabilize? Would you agree that the current d84 on the right side is gravel size? And the d84 on the far side is cobble?

Plate B5 shows some geologic structure and stream layers.

B5 UL shows sedimentary layers ranging from sandstones (buff & coarse visual texture) to shales (gray & fine texture). Would you conclude, on the basis of the difference in visual texture, that shales would be more unstable than the sandstone? Now ignore the rock type and consider just the angle of the layer, why might a road cut along the grain (left side) be more unstable than a road cut across the grain (right side)?

B5 UR shows a closer view of interbedded sandstone and shale. In this case, the thin shale layers are softer material, erode more easily, and would tend to form seeps. Assuming that the rocks were cut off at the picture edge, would you conclude that potential land slide would depend on the strength of the shale and its moisture condition?

B5 LL shows recent alluvial layers includes two buried soils. The soils are more cohesive than the surrounding sandy layers. The material exposed in the vertical bank contains very little clay and shows layers of sand mixed with layers of gravel and sand.

B5 LR is near B5 LL, but a weak sand lens is more obvious. Below the sand lens are deposits of small and medium gravels; above the sand lens soil material is developing.

<u>Field Exercise:</u>

1) Take a look at the character of some nearby exposed banks, either road or stream banks will do. Look for the features associated with probable zones of weakness and estimate the d84 of the material that is likely to be providing the strength. In particular, look for sandy lens or zones that are limited in cohesive material. Can you tell what the geomorphic history is?

2) Make the same observations for several stream reaches for the zone at or below the expected bankfull water stage.

>>>> Mark the geologic rock types that dominate in the stream feature; be aware of unusual combinations like shale overlain by sandstone cobbles.

Form choices: basalt, granite, limestone, marine shales (high salt), mixtures like outwash, rhyolite, schist, sandstone, shales, volcanics.

Weathering of particular rock types also produces characteristic chemical mixtures that dictate long term stream productivity and response to chemical impact. In particular, low levels of hardness and alkalinity are of concern: first, because the low buffering capacity can be overwhelmed by spates of acid rain or snow; and second, cadmium, copper, lead, nickel, silver, and zinc ions are more toxic at lower levels of hardness.

With general knowledge of local rock types and where they are located, you have a good start on how and why streams behave the way they do. The study sheet (pocket) has some suggestions for looking at the landscape to see what sort of geology might be expected. Plan to spend some time just wandering around.

If you do not already know the local rock types, buy a sampler from a local rock or curio shop. The most useful is a 10" or 12" flat, but sturdy, partitioned box with maybe 2 dozen 1" samples. Be sure that each sample is numbered to fit the name key. Practice using the following field key with the rock samples. Then, on a warm pleasant day, go find some local rocks and key them out. Check with a geologist or the owner of the rock shop to verify your choices.

The 3 great genetic groups - igneous, sedimentary, and metamorphic - are also descriptive of their physical and mineralogical processes.

Igneous	
Rapid cool-	Fine-grained, a mixture of unrecognizable minerals; the only inherent structure is that of the flow lines.
Slow cool	Coarse-grained, no noticeable structures in the hand specimen, and composed of common identifiable primary minerals (quartz, feldspar, mica, dark minerals).
Sedimentary-	Mainly a single, low-temperature mineral; banded, stratified, and often fossiliferous.
Metamorphic-	High-temperature minerals, like those of the plutonic rocks, but banded, stratified, and, as general rule, with a concentration of a single mineral in a formation.

Some rules of thumb :

a Rocks with non-interlocking (clastic) texture are always sedimentary.

b Interlocking (crystalline) texture - igneous, sedimentary, or metamorphic:
- with fossils are always sedimentary.
- with oriented texture (foliation) are usually metamorphic.
- with random texture and mostly silicate minerals are usually igneous.
- with large crystals of quartz or calcite - metamorphic.
- with small crystals of " " " - sedimentary.

c Crystals too small to see size or arrangement, try these rules:
- reacts to HCl acid - probably sedimentary.
- smells earthy, is easily crumbled or flaked - probably sedimentary.
- hard, difficult to scratch on fresh surface - probably igneous.
- hard, breaks into flat sheets - probably metamorphic.

Igneous rocks

Group includes molten or plastic magma forced to the surface (extrusive), forced into fissures or between layers of existing rocks (intrusive), or allowed to cool very slowly (plutonic).

Extrusives - (fine grained; can not see individual grains w/ hand lens)-

- Obsidian is a comparatively rare glassy rock that has not crystallized at all; often gray to black, sometimes streaked with brownish red and black. Obsidian is high in silica & the uncrystallized equivalent of granite.
- Felsite is generic for all light-colored (light gray, yellow, pale & deep red) fine-grain extrusives. Rhyolite is a felsite equal to granite.
- Basalt is a fine-grained black lava rock composed largely of microscopic grains of feldspar, pyroxene, and olivine, but with no quartz.

Intrusives - traprock; thin seams; some grains large enough to see.

- Porphyry is like a frozen rock mush, with isolated crystals (phenocrysts) of some mineral embedded in a felsite or basalt ground mass. Feldspar, quartz, pyroxene, and olivine are common phenocrysts.
- Diabase forms when feldspar grows to form lathlike crystals then fills in with dark minerals; known as diabasic texture; a common traprock type.

Plutonic rocks - even-sized grains, coarse-texture (1mm to 1cm plus).

- Granites are usually light gray, white, pink, black, or yellow-brown combinations of quartz & orthoclase feldspar with some dark mineral. Pegmatite (very coarse granite) can have crystals several feet across.
- Diorite is a group name for dark colored granite-textured rocks rich in plagioclase and low in quartz.
- Gabbro is still lower in silica and darker in color than diorite.

Sedimentary rocks

Rocks exposed to air and water eventually break down. Freeze and thaw aid in mechanical rock disintegration; individual grains are freed. Chemical weathering changes feldspars into clay & releases quartz grains. Deposits may be water-laid, wind-laid, or ice-laid. Some deposits, like glacial drift, are unconsolidated mixtures, while others are welded together by pressure and cemented with iron or calcium. Some common ones are:

- Arkose is from mechanical disintegration w/ little chemical change; grains are both quartz and feldspar. Banding is not obvious.
- Conglomerate is composed of rounded water-worn pebbles cemented together.
- Breccia is like conglomerate, except the pieces are angular.
- Sandstone is composed of sand grains cemented together (often with iron); colors of white, gray, yellowish, or dark red.
- Shale is mainly clay particles, often with a little sand intermixed.
- Limestone shows mainly as a fine grained calcium carbonate precipitate or lime deposits removed by living organisms (lots of shell structures).
- Dolomite resembles limestone, except that it is richer in magnesia.

Metamorphic Rocks

Contact metamorphism occurs when magma is forced into the existing rocks. In addition to heat and pressure effects, magma gases soak out ahead of the magma and permit the growth of different minerals, like the metal sulfides.

Regular metamorphism occurs under tremendous heat and pressure. Rocks lose moisture, oxygen, and carbon dioxide picked up during surface exposure resulting in new mineral makeup. The selective effects of weathering and sorting will show up in the new mineral purity or deposition patterns. Clays, for example, will revert to the ancestral mica and feldspar but retain the banding created during deposition.

- Slate is from shale; mica growth is perpendicular to the pressure resulting in an easy cleavage plane; shows luster (but no mica crystals).
- Phyllite is the next step; the new mica crystals have grown larger to give a distinct micaceous luster and parting cleavage to the rock.
- Schist is the final product for hydrated and oxidized clays. The final rock is predominantly mica and is easily fractured along the cleaveage. The micaceous banding makes schist distinct from any primary rock.
- Gneiss is from sandy shale, shaly sandstone, or fresh granite; gneiss shows granite texture and color plus gray to almost white bands. Gneiss has much less mica than schist (but may show a mica-rich cleavage).
- Quartzite is from sandstone. There is little change in the quartz grains other than being welded together; fractures across grains like a solid rock. Quartzites are hard and the most resistant of all rocks. They tend to retain sandstone colors: brown, yellow, gray, reddish, or white.
- Marble forms from limestone and dolomite. A coarsely crystalline white or colored marble results from fairly pure carbonates; used for decoration.

ARTIFICIAL KEY TO COMMON ROCKS

1	Particle arrangement - non-interlocking	go to 2
	- interlocking	go to 3
	- foliated	go to 5
	- microscopic	go to 6
	- glass like, usually black	= obsidian
2	With quartz, feldspar, fragments, or clay minerals:	
	- particle size > 2mm, rounded	= conglomerate
	- " " " " , angular	= breccia
	- particle size .0625 to 2mm, quartz	= sandstone
	- " " " " , feldspar	= arkose
	- particle size <0.0625mm	= shale or mudstone
3	With minerals:	
	- nearly all quartz, coarse, welded	= quartzite
	- nearly all calcite, small crystals	= limestone
	- " " " , large crystals	= marble
	-silicates (quartz, feldspar, dark minerals)	go to 4

4 Grain is Coarse (1mm+):
- light colored, quartz & feldspar = granite
- dark colored, feldspar, no quartz = gabbro

4 Grain is fine (< 1mm):
- light colored, quartz & feldspar = felsite
- dark, commonly porphyritic = basalt

5 Foliated
- paper like, mica obvious = schist
- banded = gneiss
- plate like = slate

6 Microscopic - fine grained
- scratch knife, light color, w/ sedimentary = chert
- " " " " w/ igneous = felsite
- " " , dark color, w/ igneous = basalt
- knife will scratch, color varies, = limestone
- " " " , " " , earthy odor = shale or mudstone
- " " " , foliated, mica luster = slate

Common minerals field clues:

Black	Dull, Hard, Box	Pyroxene
	Bright, Hard, Box, Cleavage, (w light color min)	Amphibole
	Bright, Cleavage, Flakes	Biotite
	Dull, Scratches, Reacts	Calcite
	Bright, Cleavage, Hard, w/ pyroxene	Plagioclase
White- -gray	Bright, Cleavage (Striations), Box	Plagioclase
	Bright, Cleavage (no Striations)	Orthoclase
	Bright, Cleavage, Scratches, Reacts	Calcite
	Dull, Scratches, Reacts	Calcite
	Dull, Scratches, no-React	Gypsum
	Bright, Flakes, Cleavage	Muscovite
	Bright to Dull, Hard, Irregular, "greasy" look	Quartz
Tan-Cream	Dull, Scratch, Reacts (powder only)	Dolomite
Pink-red	Bright, Cleavage, Box	Orthoclase
	Bright, Cleavage, Reacts	Calcite
	Bright, Hard, "Spherical"	Garnet
Green	Bright, Cleavage, Hard, Box	Orthoclase
	Bright, Hard, "Spherical"	Olivine

Hard= does not scratch w/ knife. Box= boxlike shape. Reacts= with HCl acid.

>>>>   **Channel Physics** - stream health is sensitive to stream energy and channel geometry changes. Obtain **Watershed area & mean elevation** from the map.

>>>>   Use a mounted 5x hand level & survey rod (or cord & line) to measure **Channel Slope** (water surface); do it carefully.

>>>>   Note if this is a **Step-Pool** system.

Some streams develop a **step-pool** structure. The step is a local gradient control imposed by features such as rock ledges, boulders, or large woody debris.

When you are looking around, be aware that many **step-pool** systems were used for early-day log or tie drives and have not yet recovered. So what you might be seeing is a "used-to-be" **step-pool** system with severe stability problems.

>>>>   **Sinuosity** - ratio; chnl len/valley length. Outer bank curve radius '.

Sinuosity is important as a descriptor or a measure of central tendency in long term stream adjustments. **Outer bank curve radius** is specific and is used to evaluate the effects of erosional forces on channel stability.

>>>>   **Bankfull Width & Depths** - take time to find good bankfull indicators. From width and average depth (from Qbf line); calculate W/D ratio.

Mark **Bank X/Y** (cotangent) ratio; for the same materials, steep bank sections are more erosive than gentle bank slopes.

>>>>   **Channel Deposition** - % reach with point bar, side bar, mid-channel bar, islands, blocks & cutoffs, tributary delta bars, or pedestals (bank remnant). Count jams that block more than 1/4 Qbf stage.

>>>>   Select features that create **Bed Stability** and record rock size (mm) & major elements of stable lwd.

There are 2 points here that apply to coarse bedded-streams. First, changes in channel shape and structure, including sequences of riffles, pools, runs, glides, scour pools, and boulder cascades, mainly happen when flow events are high enough to move the channel bed coarse fragments. Because riffle bars represent the first material dropped after a high flow, they contain assortments of the stream's largest particles. Current experience suggests that the size of riffle material is a good measure of bed stability and reflects the stream's durability to maintain geomorphic equilibrium under climatic variations.

Second, the risk of serious channel stability problems accelerates if flows capable of bed scour or bank erosion become more frequency or if there is a substantially greater sediment supply. The initial channel response to more

stream power or more sediment loading is to reduce bedform roughness, usually by filling pools with sediments. Subsequent channel adjustments include increasing the extent and number of depositional areas and riffles, with corresponding changes in width, depth, meander patterns, or longitudinal profile. Taken together the result is fewer and shallower scour pools, loss of stable woody debris, and loss of habitat diversity.

Other things being equal, the risk of bed stability problems, and the likely effects on habitat depth and substrate, can be inferred from a comparison of riffle material data from appropriate reaches. From a watershed perspective, riffle d84 data on several stream reaches suggest spatial distributions of past sediment history: for example, old sediment slugs tend to even out as they move down stream, whereas new spills tend to decrease d84 as you go upstream with abrupt changes to larger d84s above the sources. Systemwide low d84s (compared to reference) indicates long term active sediment sources.

>>>> **Banklands** - Mark the bank **material origin** - residual, glacial, mass movement, terrace or lake deposits, or a jackstraw mix of large woody debris and soils as might be found in an area of beaver dams or landslides.

Bankland Slope- % slope of non-bedrock mtrls above the outer bank curve.

>>>> **Downcut depths** (ft) - measure from channel bottom to 1st bench where flows will no longer be confined. If there is a 2nd bench, flag & note height from its toe to top.

Take your measurement where the thalweg is near the center of the stream and the downcut depth is typical of local features. Several patterns are common:

```
 ___   ______        ______        ______     ___      ___
    \___/    [a]           \___      ___/  [b]    \__      /  [b]
                               \__/        [a]       \___/    [a]
```

For example, [a] is 1st bench; [b] is 2nd bench.

>>>> For **Stable length** (% reach length), check the straight and outside curves for bankfull indicators; what % are aged and well marked, what % are raw site? In evaluating vegetation -- count only durable and/or fibrous root systems and large structural features. Look carefully; banks with new instream features or newly grassed conditions may still be unstable.

Instability triggers - Beaver; high flows (& dam operation & floods); burns; farming; grazing; logging; jams; mine & road side cast; off-road vehicles; pipe (easily sugared, piped, sand lens); head wall; head cut; snagging; overbank flows; seeps & slumps; debris avalanche.

Stable Length integrates flow velocity in relation to channel materials, curvature or meander radius, flow depth, bank back slope, and bank vegetation.

Look for instability and signs of stream adjustment. Try to understand the stream system well enough to identify the causes, correct the problems, and anticipate future trends and consequences. Questions to ask:

Will the coarse bottom material in the thalweg prevent down cutting? Stability can be provided by coarse material on the bed. T-Walk uses the d84 as a measure of this stability. If you know high flow surface velocity over the thalweg, then the armor size, mm = (VEL '/s)^2 is a rough guide.

Is the thalweg position being shoved to the side? Do you see fresh bar material being deposited in the direction of the thalweg. In particular, look for a developing shift in size or coarseness on mid-channel or point bars that tend to force flows out of the existing thalweg. As the bar material becomes more resistant to erosion, the downstream opposite bank is subjected to increased attack.

Will the banks remain stable with the expected thalweg changes? Look to see if the toe of the bank is being undercut or vegetation is being undermined enough to cause the bank to collapse.

<u>Photo Review</u>

B1 UL.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B1 UR.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B1 LL.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B1 LR.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B4 UL.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B4 UR.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B4 LL.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no
B4 LR.	Will the thalweg material prevent down cutting?	yes	no
	Is the thalweg position being shoved to the side?	yes	no
	Will the banks remain stable with expected changes?	yes	no

>>>> <u>T-Class</u> (Thalweg stream and bankland regimes) - includes physical process factors important for maintenance and restoration of stream systems. **T-Class** is an open ended classification designed to incorporate existing & potential typic model interpretations. Make **T-Class** specific; code unusual subsurface materials, bimodal distributions, and equilibrium modifiers.

T-Class currently has codes for geologic origins, channel and bank material, stream gradients, perennial or periodic flows, and equilibrium shifts. Each criteria is tracked separately using a generic, open ended nomenclature; this supports a hierarchal inventory approach from air photos and maps to field studies. Uppercase letters denote process related factors, lowercase letters denote materials, and numbers denote measurements. The upper and lower case are specific; a lower case "s" means "sand", while an upper case "S" means "Step". Each letter is only used once and was chosen to help the field technician remember what they stand for. Where information on materials (lower case) is to be included, show it with the correct upper case letter code(s).

There are 2 major dimensions to be coded: Stream regimes and bankland regimes.

<u>Stream regimes</u> - geomorphic stream equilibrium character:

A type Aggressive; stream power is sufficient to keep excess sand sediment from accumulating even during low flow seasons; 90% of water year has 'hungry water'. Depositional features rare. 4- <10% slope.

B type Balanced; stream power is sufficient to move excess sand sediment load and flush out pools during seasonal high water. Sediment accumulates during low flow conditions. Depositional features common; point bars usually truncated. 1.5- <4% slope.

C type Cumulative; stream lacks power to move excess sand sediment load; pools and riffles common; well developed sinuosity. Depositional features abundant; point bars well developed. 0.5- <1.5% slope.

F type Flat; sand and fine materials common; bedforms if present are sediment transport related. Deposition forms abundant. <0.5% slope.

H type Hydraulic; stream power is sufficient to create hydraulic transport of coarse fragment bed materials (d50 = 0.25 - 1.5'). 10% &> slope.

- **Modifiers** are added to define equilibrium shifts (as needed):

D <u>Debris</u> modifier; large quantities of all sizes forces channel braiding; surface water reduced; frequent channel change. Ex: CD

I <u>Incised</u> modifier; accelerated down cutting; rejuvenation. Ex: BI

N <u>Narrowed</u> modifier; channel width reduced; e.g. land slide, road fills, sedimentation, or vegetative encroachment. Ex: CN

P <u>Periodic</u> modifier; direct flow response to precipitation; wash, gully, episodic, intermittent, ephemeral, arroyo, coulee. Ex: AP

S Step modifier; step-pool systems. Cascade pool/riffle sequence; log sills; bedrock ledges; concrete grade control. Ex: BS

W Widened modifier; channel width expanded; e.g. bank collapse from trampling or flow generated lateral migration. Ex: BW

X eXcavated modifier; channel has been constructed, moved, shifted, channelized, re-routed, shortened, or "improved". Ex: CX, FIX

Z Zero modifier; zero flows expected seasonally in perennial streams, e.g. diversions or reservoir effects. Ex: AZ, BZW

- **Channel materials** in the active channel material.

Applies to surface and subsurface material where surface is defined by the d84 size (84% less than selected diameter). Normal code structure uses lower case alpha code for channel material size category:

r = bedrock, b = boulders, c = cobbles, g = gravel, s = sands,
f = fines (silt & clay), m = mud & muck, l = large woody debris.
d = deposits of recent, fresh, soft or unconsolidated materials.

Ex: 'Ag' stream = Aggressive, gravel surface.
'AZg' stream = Aggressive, zero flow, gravel surface.

Surface code reflects an expected log-normal size distribution of material. Subsurface codes are added when there is a misfit between the surface and the subsurface; e.g. a sandstone cobble underlain by a fine grain shale with minor amounts of intermediate sizes. Another example is sand loading from road erosion.

Ex: 'Bcf' stream = Balanced; cobble surface; fine subsurface.
'Bsc' stream = Balanced, sand has covered over a cobble bottom.

Bankland regime - geologic and geomorphic character of the banks.

General character that reflects past events like glaciation, medium term climate cycles, valley development, or large flood events.

G type - Glacial; glacial processes; moraines, till, drift deposits.
M type - Mass movement; dominated by earthflows, soil creep, slides.
R type - Residual; dominated by colluvial processes and bedrock materials.
T type - Terrace; fluvial processes; material tends to be water worn.
L type - Lake; deposits exposed by lowering water or by land lift.
J type - Jackstraw; flow & erosion patterns modified by surface and buried wood debris; e.g. beaver dams or blow down.

- **Bank height** - channel bed to top of bench(es), feet.

If there are several benches, code each one as a sequence.

Ex: 'Bc2T' = Bc channel cut in 2' terrace deposits.
'Ab4R' = Ab channel cut in 4' residual materials.

- **Shear zone strength** - Bank strength depends on the weakest elements.

Determine the size material that provides the interlock skeleton; code the d84 of the most likely failure zone. Use the material size category:

r = bedrock, b = boulders, c = cobbles, g = gravel, s = sands,
f = fines (silt & clay), m = mucks or muds, l = large woody debris.

Ex: 'Bc2Tg' = Balanced, cobble, terrace, 2'deep, gravel shear zone.
'Cg24Ms' = Cumulative, gravel, 24' mass failure, sand shear zone.
'BWgG' = Balanced, Widened, gravel surface, glacial deposits.

T-Class Letters Alphabetic List

Letters are used just once. Capital letters are process related; lower case are codes for materials.

A	Aggressive	a	
B	Balanced	b	boulder
C	Cumulative	c	cobble
D	Debris	d	deposits
E	Estuary (null in R-2)	e	
F	Flat	f	fines
G	Glacial	g	gravels
H	Hydraulic	h	
I	Incised	i	
J	Jackstraw	j	
K	-	k	
L	Lake	l	lwd
M	Mass movement	m	muds
N	Narrow	n	
O	-	o	
P	Periodic	p	
Q	-	q	
R	Residual	r	bedrock
S	Step	s	sands
T	Terrace	t	
U	-	u	
V	Reserved for vegetation	v	
W	Widened	w	
X	eXcavated	x	
Y	-	y	
Z	Zero	z	

There are 5 slopes classes: write the slope breaks next to the codes.

There are 8 equilibrium codes: what are they?

There are 6 geomorphic and geologic codes; what are they?

How many combinations of slope and geologic material are there?____________

How many combinations of slope and equilibrium modifiers are there?____________

How many total combinations of slope, equilibrium, and geology?____________

How many codes for materials are there? ____________

What does "d" mean? ____________________________________

What does "lwd" mean? ____________________________________

What would you code an ephemeral gully? ____________________________

Exercise
Review the T-Class for the following combinations.

17Bq 2G ______. Stream channel of 3%, runs over bottom materials d84 = 36mm; glacial material. Stream bankfull width = 17'; top of bank is 2' high.

10Cq 2R ______. Stream channel of 1%, runs over bottom materials d84 = 12mm; residual material. Stream bankfull width = 10'; top of bank is 2' high.

4Ab 1R ______. Stream channel of 6%, runs over bottom materials d84 = 400mm; residual material. Stream bankfull width = 4'; top of bank is 1' high.

8Ac 7R ______. Stream channel of 8%, runs over bottom materials d84 = 200mm; residual material. Stream bankfull width = 8'; top of bank is 7' high.

10BSc 2Tc ____. Stream channel of 2%, step pool system; runs over bottom materials d84 = 100mm. Terrace material, d84 = 100. Bankfull width = 10'; top of bank is 2' high.

______________. Stream channel of 8%, runs over bottom materials d84 = 300mm; glacial material. Stream bankfull width = 12'; top of bank is 3' high.

24Ccs 1Tq ____. Stream channel of 1%, runs over bottom materials d84 = 100mm with secondary sand from road failures. Terrace deposits, d84 = 24mm. Stream bankfull width = 24'; top of bank is 1' high where it enters floodplain.

24ZCcs 1Tq ____ Same channel as above except the flow is 100% diverted 4 months of the year.

12IFs 7Tq ____. Stream channel < 0.5%; but has been cut down by flash storm runoff. Sandy bottom. Top of bank is 7' in terrace deposits with gravel d84.

______________. Same channel as above except flow is naturally intermittent.

______________. Stream channel of 1%, bottom materials d84 = 100mm; residual material. Stream bankfull width = 24'; top of bank is 8' high. Channel has been constructed to avoid putting in 2 bridges; new channel length is 1200'.

______________. Flash flood has carved out a 62' wide channel; gravel bottom; channel slope is 1%; flood plain is 4' higher than bottom.

______________. Road construction side cast and rip-rap has reduced stream width from 24' down to 16'. Bottom materials d84 = 400mm; terrace material with a 2' thick soil and ash layer caused by past flooding from a burned watershed. Top of bank is 2' high. Stream channel of 6%.

______________. Stream channel of 1%, runs over bottom materials d84 = 24mm. Stream bankfull width = 15'; top of bank is 2' high. Side hill is fine grain volcanics with seeps and numerous slumps.

______________. Stream channel of 1%; sandy bottom; 2' wide channel; 1' deep. Terrace material. First channel is in the bottom of an old gully blowout that is 15'deep with gravel bank material.

______________. How many combinations are possible with T-Class?

Photo Review

1) Look at each photo and make your best guess as to the T-Class factors that you can see or interpret. The letters are defined as before; use the "?" along with the code when making a guess. Then compare with the form answers. Feel free to have different answers. Be sure to discuss your differences.

Photo	Gradient materials	Equilibrium Shifts	Bankland materials	T-Class
B1 UL	? A(B)C F H m f s g c(b)r l	D I N P S W X Z d ? ok	? G M(R)T L J m f s g c(b)r l	________
B1 UR	? A B(C)F H m f s(g)c b r l	D I N P S W X Z (d) (?) ok	? G M R(T)L J m f s(g)c b r l	________
B1 LL	?(A)B C F H m f s g(c)b r l	D I N P S(W)X Z d ? ok	? G(M)R T L J m f s(g)c b r l	________
B1 LR	? A(B)C F H m f s g c b(r)l	D I N P S W X(Z) d ? ok	? G M(R)T L J m f s g(c)b r l	________
B4 UL	? A(B)C F H m f s g c(b)r l	D I(N)P S W X Z d (?) ok	? G M(R)T L J m f s g c(b&r)l	________
B4 UR	? A B(C)F H m f s g(c)b r l	D I N P S(W)X Z d ? ok	?(G)M R T L J m f s g(c)b r l	________
B4 LL	? A(B)C F H m f s g c(b)r l	D I(N)P S W X Z d ? ok	? G M R(T)L J m f s g c(b)r l	________
B4 LR	? A(B)C F H m f s g(c)b r l	D I(N)P S W X Z (d) ? ok	? G M R(T)L J m f(s&g)c b r l	________
D1 UL	? A(B)C F H m f s g(c)b r l	D I N P S W X Z d ? ok	? G M R(T)L J m f s g(c)b r l	________
D1 UR	? A(B)C F H m f s g(c)b r l	D I N P(S)W X Z d ? ok	? G M(R)T L J m f s g(c)b r l	________
D2 UL	(?)A B(C)F H m f s g(c)b r l	D I N P S W X Z d ? ok	? G M R(T)L J m f s g(c)b r l	________
D2 UR	? A B(C)F H m f(s&g)c b r l	D I N P S W X Z (d) ? ok	? G M R(T)L J m f s(g)c b r l	________
D2 LL	? A B C(F)H m(f)s g(c)b r l	D I N P S W X Z d ? ok	? G M R(T)L J m f s g(c)b r l	________
D3 UL	? A(B)C F H m f s g c(b)r l	D I N P S W X Z d ? ok	? G M R(T)L J m f s g c(b)r l	________
D3 UR	? A B(C)F H m f s g(c)b r l	D I N P S W X Z d ? ok	? G M R(T)L J m f s g(c)b r l	________

D3 LL	? A(B)C F H	D I(N)P S W X Z	? G M R(T)L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
D4 UR	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s(g)c b r l	d ? ok	m f s(g)c b r l	____
D4 LL	? A(B)C F H	D I N P S W X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
D5 UL	? A(B)C F H	D I N P S W X Z	? G M(R)T L J	
	m f s g c(b)r l	d ? (ok)	m f s g c(b)r l	____
D5 UR	? A(B)C F H	D I N P S(W)X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
D5 LL	? A(B)C F H	D I N P S W X Z	? G M R(T)L J	
	m f s(g)c b r l	(d) ? ok	m f s(g)c b r l	____
D6 UL	? A(B)C F H	D I N P(S)W X Z	? G M(R)T L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
D6 UR	? A B(C)F H	D I N P S(W)X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
D6 LL	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
D7 UL	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s(g)c b r l	d ? ok	m f s(g)c b r l	____
D7 UR	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
Q1 UL	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
Q1 UR	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s(g)c b r l	d ? ok	m f s(g)c b r l	____
Q1 LL	? A(B)C F H	D I N P S W X Z	? G M(R)T L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
Q1 LR	? A(B)C F H	D I N P S W X Z	? G M(R)T L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
Q2 UL	? A(B)C F H	D I N P S W X Z	? G M(R)T L J	
	m f s g c(b)r l	d ? ok	m f s g c(b)r l	____
Q2 UMid	(?)A B C F H	D I N P S W X Z	? G M(R)T L J	
	m f s g c b(r)l	d ? ok	m f s g c b(r)l	____
Q2 LL	? A B(C)F H	D I N P S W X Z	? G M R(T)L J	
	m f s g(c)b r l	d ? ok	m f s g(c)b r l	____
Q2 LR	? A(B)C F H	D I N P S W X Z	? G M R(T)L J	
	m f s(g)c b r l	d ? ok	m f s(g)c b r l	____

>>>> **Thalweg Standard** (T-std) - defines conditions of Robust health possible for the study reach and provides the necessary CWA goal comparison. It is essential to match the **Thalweg Standard** to project conditions for valid comparisons. If Robust stream health conditions exist, then use 'before/after' or 'above/below' comparisons to determine Stream Health.

>>>> Record the name, **T-Class** at equilibrium, and **Tarzwell Substrate Ratio** for the Thalweg Standard. If **T-Class** is different, then select an off-site Thalweg Standard with the same T-Class.

For your area, start a notebook of T-Standards that show long term natural conditions, complete with pictures and full descriptions. Be sure to keep in touch with State water quality people, so your notebook will include their stuff as well as what you'd done. Also share around with other Ranger Districts for reference conditions that you can also apply.

A critical piece for this reference is a set of superior and double excellent photographs. You will rely on these, so take care to get the best. Take pictures facing upstream, downstream, both banks, AND several of the substrate.

What information would you put into your T-Standard notebook?

How would you organize the photos?

>>>> If Robust conditions are absent, then antidegradation is also at issue. Record the existing **T-Class** and **Tarzwell Substrate Ratio** that defines the antidegradation limits.

>>>> **T-WALK** study identification & date - make it clear; name the **Watershed folio** used to store such data and cross file any **Samples & photos.** Do it well; to quickly find data & use for later analyses makes you look ready for promotion.

T-Walk Study site ID needs to be site specific so the data place is not lost. In part, study sites need to be field monumented in ways compatible to the decision time frame. For example, a concrete benchmark would provide field location for 50 years as might be necessary to document a water right; whereas, a steel rebar or wooden stake wouldn't last that long. The important point is to think ahead so today's efforts will contribute to future understanding.

Current experience suggests that finding a previous field plot requires both a structured naming protocol and a series of maps or sketches. The acrostics "SITE" and "GRASP" are used to help remember the factors and sequence:

- SITE name as N4416 E410; Trout Creek; South 8960.
  - S = map Square such as Universal Transverse Mercator (UTM); Lat/Long; or Township, Range, Section. Try UTM first; the 1:24000 topogs and orthophotos have 1km tics & the 1:50000 county topogs have 5km tics. For a label, use the lower left UTM corner because UTMs increase going north and east. Be aware that longitude decreases going east.
  - I = Identification sequence of major to minor stream name such as Willow Creek UNT (unnamed tributary). Include the watershed code, if any.
  - T = Trending direction of downhill or flow will help separate out nearby sites. Use at least the 8 compass points.
  - E = Elevation of low end of reach picked from a 1:24000 topog is adequate. Try using a field barometer adjusted to local benchmarks.

- GRASP sequence of general, road, access, site, and pool maps.
  - G = General vicinity -- prefer 1/2"/mile scale with towns and roads;
  - R = Roads -- prefer 1:24000 topographic with roads, trails, and streams;
  - A = Access sketch of how to get there including distances and landmarks;
  - S = Site sketch of benchmarks, cross-sections, and sample points; and a
  - P = Pool sketch of stream features including pools, rocks, and bars.

Field Exercise

1) Select a 1:24000 USGS topographic map; find 3 streams and locate points. Then using UTM's write a "SITE" identification for each point.
2) Pick a reach, and prepare a GRASP map sequence. If you are short on time, skip the General & Road maps and concentrate on Access trail, the Site sketch, and the Pool sketch.

Diversity Screen

Training for diversity includes these commitments from the trainee:

1. study Aquatic Life Health Classes and Diversity Screen Interpretation;
2. study field book drawings of plants and animals;
3. study photographs of different channel conditions;
4. spend time with a trainer looking at local streams;
5. work several streams to perfect techniques; and
6. call for a 2nd visit from the trainer for a consistency check.

Background Key Ideas

The diversity screen is Clean Water Act directed and takes a broad look at aquatic life and selected terrestrial and aquatic habitat features as it might support ecosystem diversity. These individual factors are matched against the CWA standard of an unimpacted stream; i.e. what it takes to be Robust Stream Health. There are three fundamental questions:

What is it now?
What should it be?
What needs to be fixed?

The field evaluation is not subtle; its purpose is to identify Stream Health using an analysis of physical and habitat factors. Recall that Stream Health Class is a combination of both production and ecosystem stability and diversity as defined by the Aquatic Life health class. This was provided earlier; but it may be helpful in tracking major biological shifts from one class to the next:

Adequate: does not reach full potential of Robust condition. For example, you may have a well balanced fish community, good age structure, and sensitive species; but individual fish are not up to their potential growth. Some possibilities include habitat features that have been modified, or the fish population has expanded greatly, or not all food organisms are available, or they are available in fewer numbers.

Diminished: the community is no longer balanced, one or two tropic levels may dominate, and the age structure is not stable. The total number of fish may be quite high (relative to Robust) but individuals tend to be small. Sensitive species is present, but not flourishing. Less sensitive species make up the majority of the biomass.

Impaired: Few sensitive species are present. Age structures are unstable.

Precarious: No sensitive species are present.

Catastrophic: No longer has capability to support fish of any kind.

>>>> Diversity Screen Interpretation -

If you can not match the stream reach against a **T-Standard**, the next step is to go directly to the Aquatic Life Health Class table, and make a determination. The following table gives you a first cut by focusing on one Diversity Screen parameter at a time. Read across the table and select the likely Reference condition, then down the Site column to match current or expected condition. If they are the same the table shows Robust (R) health. For Sites that are impacted and of less quality than the Reference, the table shows the decline in health. (If Reference 10 Cobble Count = 128, and Site = 64, then read 'D' from table).

The table is a 'best guess' interpretation, so do not fuss over single factors. Look for patterns among the factors that support or confirm a particular Aquatic Life Health determination. However, this step is not an averaging; if an individual factor is clearly controlling, then it determines the health class.

Temper the table's results with what you know of the area, it's recent climate and management history, and expected impacts in the future. Then, if conditions are not what they should be, the limiting factors suggest a beginning for restoration planning. For example, if Shore depth should be 2' and it is only 0.2', one part of restoration might be to fence-protect the bank, add a log along the bank toe, back slope, and plant willow.

While it is imperative that aquatic health definitions remain biologically based (as opposed to politically or economically inspired), the actual definitions are primarily "bottom line" or "end-game" evaluations that are difficult to apply in the context of an advance warning system. For this reason, T-Walk avoids a frontal assault on the biological evaluation problem, and instead, infers aquatic life health from changes in physical and habitat factors.

Failure to maintain the physical conditions necessary to support aquatic life health constitute 'degradation' because of the antidegradation test. Substrate, cover, flow, depth, pools, and riffles are part of the Diversity Screen and the interpretations are intended to lead back to the biological definitions.

Look at the Diversity Screen Interpretation table on the next 2 pages. Note that for every factor, the table shows a "reference" line and a "site" column so that aquatic life health interpretation can be obtained by comparing "site" against "reference"; the intersection of the two gives a letter - R, A, D, I, P, or C. which refers to the 6 aquatic life health classes.

For each factor, highlight the intersections for "R", look at the pattern, and read the narrative for "Robust". Then study the pattern and look for the fringe or pivot points where individual choices might easily change.

With new highlight colors, do the same for the rest of the health classes.

Now, go back through both sheets and flag those that seems to be inconsistent with aquatic life health definitions. These particular combinations were developed for plain ordinary trout; what do you think would happen if we used another species that was more intolerant?

Diversity Screen Interpretation -

If you can not match the stream reach against a T-Standard, the next step is to go directly to the Aquatic Life Health Class table, and make a determination. The following table gives you a first cut by focusing on one Diversity Screen parameter at a time. Read across the table and select the likely Reference condition, then down the Site column to match current or expected condition. If they are the same the table shows Robust (R) health. For Sites that are impacted and of less quality than the Reference, the table shows the decline in health. (If Reference 10 Cobble Count = 128, and Site = 64, then read 'D' from table).

The table is a 'best guess' interpretation, so do not fuss over single factors. Look for patterns among the factors that support or confirm a particular Aquatic Life Health determination. However, this step is not an averaging; if an individual factor is clearly controlling, then it determines the health class.

Temper the table's results with what you know of the area, it's recent climate and management history, and expected impacts in the future. Then, if conditions are not what they should be, the limiting factors suggest a beginning for restoration planning. For example, if Shore depth should be 2' and it is only 0.2', one part of restoration might be to fence-protect the bank, add a log along the bank toe, back slope, and plant willow.

Table - Direct Interpretation of Aquatic Life Health

Site ! Reference					
Riffle insects !	2May3 St	Case:box-cone	flt-rnd-spr	scf	net
May Stone Caddis !	R				
Only 2 of M-S-C !	D				
Only 1 of M-S-C !	I				
Other macros !	P				
barren, no macros !	C				

(Sum of 10 cbls) !	0	1	2	4	8	16	32	64	128	>128
0 !	R	C	C	C	C	C	C	C	C	C
1 !		R	C	C	C	C	C	C	C	C
2 !			R	C	C	C	C	C	C	C
4 !				R	C	C	C	C	C	C
8 !					R	C	C	C	C	C
16 !						R	P	P	P	P
32 !							R	I	I	I
64 !								R	D	D
128 !									R	A
>128 !										R

Site ! Reference										
Pools - % in reach !	0%	1	5	15	33	50	67	85	95	99
0% !	.R.	P	P	P	P	P	P	P	P	P
1 !	R	.R.	P	P	P	P	P	P	P	P
5 !	R	R	.R.	I	I	I	I	I	I	I
15 !	R	R	R	.R.	D	D	D	D	D	D
33 !	R	R	R	R	.R.	A	A	A	A	A
50 !	R	R	R	R	R	.R.	R	R	R	R
67 !	A	A	A	A	A	A	.R.	R	R	R
85 !	D	D	D	D	D	D	D	.R.	R	R
95 !	I	I	I	I	I	I	I	I	.R.	R
99 !	P	P	P	P	P	P	P	P	P	.R.

max pool dep ' !	<	1'	1.5	2	2.5	3	3.5	4	5	>
<1.0 !	R	A	A	P	P	P	P	P	P	P
1.0 !		R	A	P	P	P	P	P	P	P
1.5 !			R	I	I	I	I	I	I	I
2.0 !				R	I	I	I	I	I	I
2.5 !					R	D	D	D	D	D
3.0 !						R	D	D	D	D
3.5 !							R	A	A	A
4.0 !								R	A	A
5.0 & > !									R	R

dep' & vel'/s !	<2d<1v		<2d>1v	>2d<1v	>2d>1v	
(Combinations) !	all4	any3	2x<d&>d	2x>d	2x<d	any1
all 4 !	.R.	R	R	R	R	R
any 3 !	A	.R.	R	R	R	R
2x (<2d & >2d) !	D	D	.R.	R	R	R
2x (>2d all v) !	D	D	A	.R.	R	R
2x (<2d all v) !	I	I	D	I	.R.	R
any 1 !	P	P	P	P	P	.R.

Stream bank vegetn !	grass	forb	lo-brush	-hi	conf	decid
grass !	R	P	P	P	P	P
forb !		R	I	I	I	I
low brush !			R	D	D	D
high brush !				R	A	A
conf/decid !					R	R

Site	!	Reference									
(Str bk vege cont)	!										
% for both banks	!	0	1	5	15	33	50	67	85	95	99
0	!	R	P	P	P	P	P	P	P	P	P
1	!		R	P	P	P	P	P	P	P	P
5	!			R	P	P	P	P	P	P	P
15	!				R	P	P	P	P	P	P
33	!					R	P	P	P	P	P
50	!						R	I	I	I	I
67	!							R	D	D	D
85	!								R	A	A
95 - 99	!									R	R

Root depth & density		<QbSpars	<QbDens	>QbSpars	>QbDens
<QbSparse	!	R	P	P	P
<QbDense	!		R	I	I
>QbSparse	!			R	D
>QbDense	!				R

Shores - % stable	!	0%	1	5	15	33	50	67	85	95	99
0	!	R	P	P	P	P	P	P	P	P	P
1	!		R	P	P	P	P	P	P	P	P
5	!			R	P	P	P	P	P	P	P
15	!				R	P	P	P	P	P	P
33	!					R	I	I	I	I	I
50	!						R	D	D	D	D
67	!							R	A	A	A
85 - 99	!								R	R	R

max shore depth'	!	0	.1	.2	.5	.8	1	1.5	2	2.5	>
0	!	R	P	P	P	P	P	P	P	P	P
0.1	!		R	P	P	P	P	P	P	P	P
0.2	!			R	P	P	P	P	P	P	P
0.5	!				R	I	I	I	I	I	I
0.8	!					R	D	D	D	D	D
1.0	!						R	D	D	D	D
1.5	!							R	A	A	A
2.0 & >	!								R	R	R

Site	!	Reference			
Instream vegetation	!	mold	alg	wood	root
mold	!	R	C	C	C
algae	!		R	P	P
wood	!			R	I
rooted	!				R

% in reach	!	0%	1	5	15	33	50	>
0%	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
5	!			R	I	I	I	I
15	!				R	D	D	D
33	!					R	A	A
50 & >							R	R

Lwd related pools	!	0	1	2	4	8	16	>
0	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
2	!			R	I	I	I	I
4	!				R	D	D	D
8	!					R	A	A
16 & >							R	R

Stains & precptates	!	(bank or bottom color)					
color	!	Wh	R	O Y	G B	I	V Blk
(colors from ==	!	none	iron	copper	leads	oil	unk-org)
none	!	R					
iron	!	D	R				
copper	!	C	C	R			
leads	!	C	C	C	R		
oil	!	C	C	C	P	R	
unk organics	!	C	C	C	C	C	R

color & extent	!	none	sm-patch-lg		seep	1-	2-	5-	10-gpm
none	!	R							
small patch	!	D	R						
large "	!	I	I	R					
seep	!	P	P	P	R				
1- gpm	!	C	C	C	C	R			
2- gpm	!	C	C	C	C	C	R		
5- gpm	!	C	C	C	C	C	C	R	
10- gpm	!	C	C	C	C	C	C	C	R

Photograph Review - Plates D1 - D8.

The photograph Plates show different elements of the Diversity Screen. Scan the photos generally and get a feel for the range of stream conditions represented.

Step 2 is to look at each one and work through the detail as it relates to the particular Diversity Screen element. The UL, UR, LL, and LR are notations for upper and lower, left and right panels.

Plate	D1 -	Riffle Insects. Clean water animals and 10 cobble count.
"	D2 -	Pools. % of reach, maximum depth, and velocity patterns.
"	D3 -	Stream bank vegetatn. Kind, % both banks, & root depth & density.
"	D4 -	" " "
"	D5 -	" " "
"	D6 -	Shores. % stable and undercut/overhang, and maximum depth.
"	D7 -	Instream vegetation. Kind and % in reach.
"	D8 -	Stains and precipitates. Colors and extent.

If you find yourself giving this a cursory glance, then slow up and use a hand lens to study the detail. Compare what you see on the photo with what is shown as field data on the form. What choices would you have made?

Step 3. Excerpts from the Diversity Screen Interpretation are shown for each element. Below the excerpts, Examples from the Photos indicate the conditions used for "Reference" which is based on information not necessarily obvious in the photographs. The exercise here is to compare field data (underlined) for each Plate against the Reference and determine the aquatic life health class.

Step 4. Finally, the last worksheet lists all the photos and 2 questions: given what you can see or infer from the photos, circle what you would expect aquatic life health to be and what factor(s) you think might be the problem.

>>>> <u>Diversity Screen</u> - (late season (low flow) and fair weather conditions).

>>>> **Riffle Insects** - pick up 10 fist size rocks (or equivalent) from riffle areas. Study each rock with a hand lens and record the total of all nymphs & larvae for the 10 rocks. Record presence of mayfly and stonefly nymphs, and caddisfly larvae & cases. Mayflies have lateral abdominal gills (back end looks fuzzy w/ 2 or 3 tails) & stoneflies do not (2 tails clean outline). Mark all characteristic case shape & material: organic boxlike or cones; sand grain flat, round, or spiral; loose "scaffold" of leaves, twigs, or pebbles; and webs, socks, or trumpet-like nets.

The 10 cobble count procedure tends to select free-standing rocks from riffle habitats. Such sampling favors macroinvertebrates that can either hang on or protect themselves from relatively rapid flows. Several common families of mayflies, stoneflies, and caddisflies, likely to be represented in such a riffle sample, are also sensitive to chemical changes and make a fairly simple test for chemical pollution impacts. If they are present in reasonable numbers, then water column chemistry is probably in good shape.

The 10 Cobble Count total insect count scale gives estimates of population abundance as an indication of "reasonable numbers", but they are not statistical parameters and will not meet evidentiary standards if they are treated as such.

In the field manual, study the drawings of mayflies, stoneflies, and caddis flies and note the general size (25.4mm = 1").

<u>How to Review the Photos:</u> Plate D1

D1 UL. Samples from the riffle edge in good clean gravels will give a good count. Try to sample when the flow is relatively low and/or where the velocity is low, yet sufficient to keep the gravel free of sediment. When you lift the rock, try to protect the bugs from direct flow forces. The data sheet shows a fairly common situation for a relatively infertile stream system; which in this case has a very high natural sediment load.

D1 UR. Not particularly good stuff, but fast and simple sampling on 10 rocks shouldn't cause your fingernails to fall off. However, if you do much sampling in this kind of water, use a pair of gloves. The stoneflies (count 2) may have drifted in; but count them as though they are home grown. The important thing is to make sure the sample rocks are exposed to the streamflow and not from an unflushed area.

D1 LL. The intense stare reminds us that it takes some careful looking to count the bugs. One use of the hand lens is to brighten up the dark areas of the rock by re-focusing the sun. If you pick up rocks all along the course of the channel, such as during the T-Depth & Tarzwell Substrate collection, then note the number for each rock and add it up later.

D1 LR. Sometimes washing the rocks into a pan will help with the counting. But, if you do this, still take a moment to look at the rock for signs of nets.

Field Data for Photos:

D1 UL	Riffle insects larvae & nymphs (Sum of 10 cbls)	!	2My3 St C:bx-cone flt-rnd-spr scf net 0 1 2 4 8 16 32 64 128 >128
D1 UR	Riffle insects larvae & nymphs (Sum of 10 cbls)	!	2My3 St C:bx-cone flt-rnd-spr scf net 0 1 2 4 8 16 32 64 128 >128
D1 LL	Riffle insects larvae & nymphs (Sum of 10 cbls)	!	2My3 St C:bx-cone flt-rnd-spr scf net 0 1 2 4 8 16 32 64 128 >128
D1 LR	Riffle insects larvae & nymphs (Sum of 10 cbls)	!	2My3 St C:bx-cone flt-rnd-spr scf net 0 1 2 4 8 16 32 64 128 >128

Interpretation for Photo: Plate D1

Site	!	Reference					
Riffle insects	**!**	**2May3**	**St**	**Case:box-cone**	**flt-rnd-spr**	**scf**	**net**
May Stone Caddis	!	R					
Only 2 of M-S-C	!	D					
Only 1 of M-S-C	!	I					
Other macros	!	P					
barren, no macros	!	C					

Examples from the photos:

Pg D1 UL	Ref = My3, St, C: cases	[msc]	Health	= R
D1 UR	" = " " "	[s]	"	= I
D1 LL	" = " " "	[msc]	"	= R
D1 LR	" = " " "	[msc]	"	= R

Site	!	Reference									
(Sum of 10 cbls)	**!**	**0**	**1**	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**>128**
0	!	R	C	C	C	C	C	C	C	C	C
1	!		R	C	C	C	C	C	C	C	C
2	!			R	C	C	C	C	C	C	C
4	!				R	C	C	C	C	C	C
8	!					R	C	C	C	C	C
16	!						R	P	P	P	P
32	!							R	I	I	I
64	!								R	D	D
128	!									R	A
>128	!										R

Examples from the photos::

Pg D1 UL	Ref = 64	[64]	Aq. Health	= R
D1 UR	" = 64	[2]	"	= C
D1 LL	" = 128	[>128]	"	= R
D1 LR	" = 128	[128]	"	= R

==========

>>>> Pools - record flat & pool water %, maximum depth, & temperature (optional). For 2' depth and 1'/s velocity, mark all the categories that apply.

There are several ways to estimate the reach % of pools. If you can see most of the reach, the relative difference in surface reflection is a reasonable measure of the pool%; i.e. what the photos show. T-Walk is based on field information derived from a pace transect or a pool tally taken along with thalweg depths.

How to Review the Photos: Plate D2

D2 UL. Somewhat of a typical pool - riffle sequence. Without being fussy, the distribution is roughly a 50-50 split between flat water and ripples. To get the 50-50 split, do your count through the left channel only; and disregard the riffle (foreground) caused by road construction. Max depth is about 2' and depth-velocity combinations are less than 2' deep.

D2 UL	Pools - % in reach	! 0% 1 5 15 33 50 67 85 95 99	Tmp
	max pool dep '	! < 1' 1.5 2 2.5 3 3.5 4 5 >	C/F
	dep' & vel'/s	! <2d<1v <2d>1v >2d<1v >2d>1v	

D2 UR. This was a typical pool-riffle sequence like D2 UL; but, sedimentation from road construction and winter sanding (maintenance) has filled in the pools and tended to produce shallow depths (1') and spread the streamflow patterns. What depth-velocity category(ies) would you expect to lose from sedimentation?

D2 UR	Pools - % in reach	! 0% 1 5 15 33 50 67 85 95 99	Tmp
	max pool dep '	! < 1' 1.5 2 2.5 3 3.5 4 5 >	C/F
	dep' & vel'/s	! <2d<1v <2d>1v >2d<1v >2d>1v	

D2 LL. This is a natural system on a low gradient stream. The area of riffle is the lower right corner. Although not obvious from the photograph, all possible combinations of depth and velocity patterns are present. The deep-fast water is mid-channel with deep-slow water in the left channel. Shallow-fast water is found just upstream of the riffles where the stream begins to converge, and shallow-slow is in many areas near banks and below the island.

D2 LL	Pools - % in reach	! 0% 1 5 15 33 50 67 85 95 99	Tmp
	max pool dep '	! < 1' 1.5 2 2.5 3 3.5 4 5 >	C/F
	dep' & vel'/s	! <2d<1v <2d>1v >2d<1v >2d>1v	

D2 LR. This was a typical minor pool and major riffle sequence for a steep (3% gradient) rocky stream. The "smooth and quiet water" still carries relatively high velocities. Would count the downstream "flat water" (top of photo).

D2 LR	Pools - % in reach	! 0% 1 5 15 33 50 67 85 95 99	Tmp
	max pool dep '	! < 1' 1.5 2 2.5 3 3.5 4 5 >	C/F
	dep' & vel'/s	! <2d<1v <2d>1v >2d<1v >2d>1v	

Interpretation for Photo: Plate D2

Site Pools - % in reach	!	Reference 0%	1	5	15	33	50	67	85	95	99
0%	!	.R.	P	P	P	P	P	P	P	P	P
1	!	R	.R.	P	P	P	P	P	P	P	P
5	!	R	R	.R.	I	I	I	I	I	I	I
15	!	R	R	R	.R.	D	D	D	D	D	D
33	!	R	R	R	R	.R.	A	A	A	A	A
50	!	R	R	R	R	R	.R.	R	R	R	R
67	!	A	A	A	A	A	A	.R.	R	R	R
85	!	D	D	D	D	D	D	D	.R.	R	R
95	!	I	I	I	I	I	I	I	I	.R.	R
99	!	P	P	P	P	P	P	P	P	P	.R.

Examples from the photos::

Pg D2 UL	Ref	=	50% of reach	[50]	Aq. Health	=	R
D2 UR	"	=	50% " "	[50]	"	=	R
D2 LL	"	=	95% " "	[95]	"	=	R
D2 LR	"	=	15% " "	[15]	"	=	R

Site max pool dep '	!	Reference <	1'	1.5	2	2.5	3	3.5	4	5	>
<1.0	!	R	A	A	P	P	P	P	P	P	P
1.0	!		R	A	P	P	P	P	P	P	P
1.5	!			R	I	I	I	I	I	I	I
2.0	!				R	I	I	I	I	I	I
2.5	!					R	D	D	D	D	D
3.0	!						R	D	D	D	D
3.5	!							R	A	A	A
4.0	!								R	A	A
5.0 & >	!									R	R

Examples from the photos::

Pg D2 UL	Ref	=	3'	[2]	Aq. Health	=	I
D2 UR	"	=	3'	[1]	"	=	P
D2 LL	"	=	5'	[>]	"	=	R
D2 LR	"	=	1.5'	[1.5]	"	=	R

Site dep' & vel'/s	!	Reference <2d<1v	<2d>1v	>2d<1v		>2d>1v	
(Combinations)	!	all4	any3	2x<d&>d	2x>d	2x<d	any1
all 4	!	.R.	R	R	R	R	R
any 3	!	A	.R.	R	R	R	R
2x (<2d & >2d)	!	D	D	.R.	R	R	R
2x (>2d all v)	!	D	D	A	.R.	R	R
2x (<2d all v)	!	I	I	D	I	.R.	R
any 1	!	P	P	P	P	P	.R.

Examples from the photos::

Pg D2 UL	Ref	=	any 3 combinations	[<2d]	Aq. Health	=	I
D2 UR	"	=	any 3 "	[1]	"	=	P
D2 LL	"	=	all 4 "	[4]	"	=	R
D2 LR	"	=	any 1 "	[1]	"	=	R

>>>> **Stream bank vegetation** - % total for both banks and what kind: grass, forbs, low shrub (<2'), hi shrub, conifer, or deciduous trees. Roots may be shallow (<Qbf) or deep (>Qbf) with either a sparse or dense root network.

Different riparian species and growth forms contribute shade, cover, and organic materials to the aquatic trophic structure. Land uses may cause a shift in growth form toward less desirable aquatic conditions including reduced biomass, bank overhang, and depth along the shore.

Streambank vegetation vigor is dependent on the frequency and degree of use. If the removal of biomass exceeds what the plant can easily recover, then stream protection decreases, banks erode too rapidly, and stream health declines.

The basis assumption is that stream banks with deep and dense root systems are likely to be topped by vigorous above-ground vegetation for which the current level of biomass removal is not creating stream health problems. To the extent that root systems become relatively shallow and sparse, the above-ground vegetation is less likely to be vigorous and, therefore, contribute less organic matter to the stream.

```
          \\|//    \|/                       \\|//  \/
         -------------                       ----------
         /~~|~~    /|\ \                     /~~|     |~\
 roots  /~~/|\~~     \~ \                   /~~/|\    |~ \
       /~~//|\\~~     \~ \                 /~~//|\     \~ \
      /                 \                 /~~///|\\     \~ \
 Qbf=/                   \ =  Qbf    = /~~////|\\      |  \ = Qbf
    /                     \           /~~/////|\\       \~ \
 __/                       \_________/~~//////|\\        ~ \_____
      <QbDense     <QbSparse             >QbDense     >QbSparse
```

How to Review the Photos: Plates D3, D4, and D5

D3 UL. Typical mountain forest stream with conifers and shrubs. Banks are well covered and existing biomass has been left on site.

Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D3 UR. Mountain stream shows effects from heavy sedimentation from upstream landslides and land use activity. Relatively new sand and gravel bars account for the loss in vegetative cover. New vegetation on the left side is just beginning to be established on recent deposits.

Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D3 LL. Same stream as UL. This channel was constructed in 1970 to avoid building 2 Interstate bridges. State-of-the-art construction techniques were used to stabilize channel banks and install fisheries improvement structures. This was an award winning effort, complete with a 20 minute video tape and ribbon cutting. Foreground shows extensive riprap added during last 10 years to reduce continuing stability problems. In 20 years, stream bank vegetation has not recovered, nor has anything else that is dependent on the vegetation.

Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D3 LR. This stream is similar in character to D3 UR except the channel has remained stable. The gravel bar deposits are typical of this geology and stream gradient. Notice the vegetative growth on the bars.

Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D4 UL. Fence line contrast in a semi-arid range type. Bunch grass and shrubs are common with some naturally bare soil bank material. Above the fence, grazing is light enough to maintain bank vegetation. Below the fence, cattle have pretty well got the best of the site. Notice the stream bottom width above and below the fence; why is that?

Above	Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
Fence	% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
	root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D4 UR. Meadow type with sodded and stable stream banks. The area is grazed but without damage.

Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D4 LL. Area used as a "sacrifice". The damage is extensive of which this is the worse. The fence line contrast indicates a grass type with some shrubs in the bottom. What little vegetation remains is sparse bunch grass.

LL (& UL	Stream bank vegetn	!	grs forb lo-shrub-hi conf decid
below	% for both banks	!	0% 1 5 15 33 50 67 85 95 99 >
fence)	root dep & density	!	<QbSpars <QbDens >QbSpars >QbDens

D4 LR. This stream bank is hammered yearly by releases from a recreation reservoir. Past grazing and logging in the upper watershed created high storm flows that blew out the beaver dams and started extensive channel cutting. The shrubs are dying out because of the lower water table; these roots are barely down to bankfull stage and was marked "<QbSpars". The bank vegetation has not recovered, nor has anything else that is dependent on the vegetation.

Stream bank vegetn	!	<u>grs</u> <u>forb</u> lo-shr<u>ub-hi</u> conf decid
% for both banks	!	0% 1 5 15 33 <u>50</u> 67 85 95 99 >
root dep & density	!	<u><QbSpars</u> <QbDens >QbSpars >QbDens

D5 UL. A mountain stream with a range of vegetation from grass to conifers. Banks are well covered and stable. Roots are dense.

Stream bank vegetn	!	<u>grs</u> <u>forb</u> <u>lo-shrub-hi</u> <u>conf</u> decid
% for both banks	!	0% 1 5 15 33 50 67 85 95 <u>99</u> >
root dep & density	!	<QbSpars <QbDens >QbSpars <u>>QbDens</u>

D5 UR. Natural flood and earth flow have scoured out the channel. The geology is prone to such floods and earthflows. Very little vegetation is left and the root systems are just beginning to re-establish.

Stream bank vegetn	!	grs <u>forb</u> lo-shrub-hi <u>conf</u> decid
% for both banks	!	0% 1 <u>5</u> 15 33 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens <u>>QbSpars</u> >QbDens

D5 LL. Fire burned most of the stream bank vegetation; the shrubs and grass that did survive make up about 1/3 bank coverage. The raw bank on the right side is an example of shallow and sparse rooting condition. Where is >QbDens?

Stream bank vegetn	!	<u>grs</u> <u>forb</u> <u>lo-shrub-hi</u> <u>conf</u> decid
% for both banks	!	0% 1 5 15 <u>33</u> 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens <u>>QbSpars</u> <u>>QbDens</u>

D5 LR. Turn-of-the-century diversion so a dam could be built. Channel was re-diverted any time maintenance was required. The dam has been abandoned and breached for safety reasons (like unstable soils). But the flow continues in this channel. In 70 years, stream bank vegetation has not recovered.

Stream bank vegetn	!	grs forb <u>lo-shrub-hi</u> <u>conf</u> decid
% for both banks	!	0% 1 5 15 <u>33</u> 50 67 85 95 99 >
root dep & density	!	<QbSpars <QbDens <u>>QbSpars</u> >QbDens

Interpretation for Photo: Plate D3, D4, and D5

Site / Stream bank vegetn	Reference: grass	forb	lo-shrub	-hi	conf	decid
grass	R	P	P	P	P	P
forb		R	I	I	I	I
low shrub			R	D	D	D
high shrub				R	A	A
conf/decid					R	R

Examples from the photos:

Pg D3 UL	Ref =	Conf, hi shrub	Aq. Health =	R
D3 UR	" =	Conf, hi & lo shrub	" =	R
D3 LL	" =	Conf, decid	" =	R
D3 LR	" =	Hi & lo shrub	" =	R
Pg D4 UL Abv	Ref =	Hi & lo shrub	Aq. Health =	R
D4 UR	" =	Grs	" =	R
D4 LL	" =	Grs	" =	R
D4 LR	" =	Grass & shrub	" =	R
Pg D5 UL	Ref =	Conf, hi & lo shrub grs	Aq. Health =	R
D5 UR	" =	Conf, hi & lo shrub	" =	R
D5 LL	" =	Hi & lo shrub	" =	R
D5 LR	" =	Conf, shrub	" =	R

Site / % for both banks	Reference: 0	1	5	15	33	50	67	85	95	99
0	R	P	P	P	P	P	P	P	P	P
1		R	P	P	P	P	P	P	P	P
5			R	P	P	P	P	P	P	P
15				R	P	P	P	P	P	P
33					R	P	P	P	P	P
50						R	I	I	I	I
67							R	D	D	D
85								R	A	A
95 - 99									R	R

Examples from the photos::

Pg D3 UL	Ref =	95% both banks	[95]	Aq. Health =	R
D3 UR	" =	67% " "	[50]	" =	I
D3 LL	" =	95% " "	[1]	" =	P
D3 LR	" =	67% " "	[67]	" =	R
Pg D4 UL Abv	Ref =	85% both banks	[85]	Aq. Health =	R
D4 UR	" =	95% " "	[>]	" =	R
D4 LL	" =	95% " "	[1]	" =	P
D4 LR	" =	95% " "	[50]	" =	I
Pg D5 UL	Ref =	95% both banks	[99]	Aq. Health =	R
D5 UR	" =	85% " "	[5]	" =	P
D5 LL	" =	95% " "	[33]	" =	P
D5 LR	" =	95% " "	[33]	" =	P

Site	!	Reference			
Root depth & density		**<QbSpars**	**<QbDens**	**>QbSpars**	**>QbDens**
<QbSparse	!	R	P	P	P
<QbDense	!		R	I	I
>QbSparse	!			R	D
>QbDense	!				R

Examples from the photos::

Pg D3 UL	Ref	=	>QbDens		Aq. Health	=	R
D3 UR	"	=	>QbDens		"	=	R
D3 LL	"	=	>QbDens	<QbSpars	"	=	P
D3 LR	"	=	>QbDens		"	=	R
Pg D4 UL Abv	Ref	=	>QbSpars		Aq. Health	=	R
D4 UR	"	=	>QbDens		"	=	R
D4 LL	"	=	>QbDens	<QbSpars	"	=	P
D4 LR	"	=	>QbDens	<QbSpars	"	=	P
Pg D5 UL	Ref	=	>QbDens		Aq. Health	=	R
D5 UR	"	=	>QbDens	>QbSpars	"	=	D
D5 LL	"	=	>QbDens		"	=	R
D5 LR	"	=	>QbDens	>QbSpars	"	=	D

>>>> **Shores** - % total for both banks w/ stable bank undercut or vegetation overhang. Record maximum shore depth (at water surface), 0.1'.

Shore condition is a simple and effective way of evaluating land use activities that can modify stream banks or stream bottoms. Habitat loss caused by grazing and road construction is common - and obvious when you look for it.

Differences in shore depth, material, and cover conditions support diversity. Undercut banks and overhanging vegetation are critical habitat for fish. To be of value, the stream banks must be stable and the vegetation close enough to provide both shade and litter to the stream. Use normal late season flow as a benchmark for shore depth, undercut, and overhang estimates.

How to Review the Photos: Plate D6

D6 UL. Well vegetated and stable banks with large woody debris make great cover for fish. Note the deep hole is under the root wad.

```
---------------------------------------------------------------
Shores - % stable & !  0% 1  5  15  33  50  67  85  95  99 >
 undercut/overhang  !
 max shore depth'   ! < .1 .2  .5  .8  1  1.2  1.5  2  2.5 >
---------------------------------------------------------------
```

D6 UR. Not much of this shore has stable undercuts or overhanging vegetation. The black line indicates where the shore is deepest and most stable. Willows were eradicated in the 1960s; heavy grazing continues.

```
---------------------------------------------------------------
Shores - % stable & !  0% 1  5  15  33  50  67  85  95  99 >
 undercut/overhang  !
 max shore depth'   ! < .1 .2  .5  .8  1  1.2  1.5  2  2.5 >
---------------------------------------------------------------
```

D6 LL. A small stream that is very stable with deepest shore about 1' deep.

```
---------------------------------------------------------------
Shores - % stable & !  0% 1  5  15  33  50  67  85  95  99 >
 undercut/overhang  !
 max shore depth'   ! < .1 .2  .5  .8  1  1.2  1.5  2  2.5 >
---------------------------------------------------------------
```

D6 LR. Natural condition with very little stable shore.

```
---------------------------------------------------------------
Shores - % stable & !  0% 1  5  15  33  50  67  85  95  99 >
 undercut/overhang  !
 max shore depth'   ! ≤ .1 .2  .5  .8  1  1.2  1.5  2  2.5 >
---------------------------------------------------------------
```

Interpretation for Photo: Plate D6

Site Shores - % stable	!	0%	1	5	15	33	50	67	85	95	99
0	!	R	P	P	P	P	P	P	P	P	P
1	!		R	P	P	P	P	P	P	P	P
5	!			R	P	P	P	P	P	P	P
15	_!				R	P	P	P	P	P	P _
33	!					R	I	I	I	I	I
50	!						R	D	D	D	D
67	!							R	A	A	A
85 - 99	!								R	R	R

Examples from the photos::

Pg D6 UL	Ref = 85% stable	[99]	Aq. Health	= R
D6 UR	" = 85% "	[1]	"	= P
D6 LL	" = 85% "	[99]	"	= R
D6 LR	" = 1% "	[1]	"	= R

Site max shore depth'	!	0	.1	.2	.5	.8	1	1.5	2	2.5	>
0	!	R	P	P	P	P	P	P	P	P	P
0.1	!		R	P	P	P	P	P	P	P	P
0.2	!			R	P	P	P	P	P	P	P
0.5	_!				R	I	I	I	I	I	I _
0.8	!					R	D	D	D	D	D
1.0	!						R	D	D	D	D
1.5	!							R	A	A	A
2.0 & >	!								R	R	R

Examples from the photos::

Pg D6 UL	Ref = 1.5' depth	[1.5]	Aq. Health	= R
D6 UR	" = 1.0 "	[0.2]	"	= P
D6 LL	" = 1.0 "	[1.0]	"	= R
D6 LR	" = 0.0 "	[<]	"	= R

>>>> **Instream vegetation** - % of reach w/ brown or grey fungus scummy mold, filamentous or matted algae, wet wood (branches & >), and rooted water plants. Count Lwd induced pools or flat water habitats in reach, #/660' reach.

Vegetation, such as mosses, other vascular plants, and woody debris, supports extensive macroinvertebrate diversity and high production rates. Stable woody debris is particularly valuable because it increases channel complexity by its effect on velocity patterns, bars, and pools as well as the distribution and retention of organic matter. Count stable or embedded woody debris that creates pools, backwaters, ponds, and combinations of slack and plunge pools. The field manual shows a few common types of water plants.

How to Review the Photos: Plate D7

D7 UL. This is a low gradient trout stream that tends to get warm in the summer. The plants (coontail) are bottom rooted and influence about 1/2 of the reach. Note in the foreground how the plants are forcing the flow into a narrower pattern. Faster velocity tends to keep the gravels clean (good habitat for insects) and redeposit fine materials around the vegetation.

```
--------------------------------------------------------------
Instream vegetation ! mld  alg  wood  root |  Lwd-pool #/r
 % vege in reach    !                      |
   #lwd pool/reach  ! 0% 1 5  15  33  50 > |  0 1 2 4 8 16 >
--------------------------------------------------------------
```

D7 UR. Wetland type vegetation that sticks up through the flow is "emergent". Look at the flow pattern; the vegetation is slowing up the local velocity and trapping fine material as a series of vegetated humps. The vegetation influences about 1/2 of the reach length.

```
--------------------------------------------------------------
Instream vegetation ! mld  alg  wood  root |  Lwd-pool #/r
 % vege in reach    !                      |
   #lwd pool/reach  ! 0% 1 5  15  33  50 > |  0 1 2 4 8 16 >
--------------------------------------------------------------
```

D7 LL. This low gradient stream tends to get warm in the summer and algae forms a coating over most of the rocks and reach length. Well over 1/2 of the reach has algae like this.

```
--------------------------------------------------------------
Instream vegetation ! mld  alg  wood  root |  Lwd-pool #/r
 % vege in reach    !                      |  (no estimate)
   #lwd pool/reach  ! 0% 1 5  15  33  50 > |  0 1 2 4 8 16 >
--------------------------------------------------------------
```

D7 LR. Several pieces of large woody debris are jammed in place because of boulders. Both the tree that is exposed and the one that is submerged are creating changes in flow patterns and location of pools.

```
--------------------------------------------------------------
Instream vegetation ! mld  alg  wood  root |  Lwd-pool #/r
 % vege in reach    !                      |
   #lwd pool/reach  ! 0% 1 5  15  33  50 > |  0 1 2 4 8 16 >
--------------------------------------------------------------
```

Interpretation for Photo: Plate D7

Site	!	Reference			
Instream vegetation	**!**	**mold**	**alg**	**wood**	**root**
mold	!	R	C	C	C
algae	!		R	P	P
wood	!			R	I
rooted	_!				R

Examples from the photos::

Pg D7 UL	Ref =	Rooted	[root]	Aq. Health = R
D7 UR	" =	Rooted	[root]	" = R
D7 LL	" =	Algae	[alg]	" = R
D7 LR	" =	Wood	[wood]	" = R

Site	!	Reference						
% in reach	**!**	**0%**	**1**	**5**	**15**	**33**	**50**	**>**
0%	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
5	!			R	I	I	I	I
15	!				R	D	D	D
33	!					R	A	A
50 & >							R	R

Examples from the photos::

Pg D7 UL	Ref =	33% in reach	[50]	Aq. Health = R
D7 UR	" =	33% "	[50]	" = R
D7 LL	" =	33% "	[>]	" = R
D7 LR	" =	33% "	[33]	" = R

Site	!	Reference						
Lwd related pools	**!**	0	**1**	**2**	**4**	**8**	**16**	**>**
0	!	R	P	P	P	P	P	P
1	!		R	P	P	P	P	P
2	!			R	I	I	I	I
4	!				R	D	D	D
8	!					R	A	A
16 & >							R	R

Examples from the photos::

Pg D7 UL	Ref =	2 in reach	[1]	Aq. Health = P
D7 UR	" =	2 " "	[0]	" " = P
D7 LL	" =	unknown	[?]	" " = ?
D7 LR	" =	8 in reach	[8]	" " = R

>>>> **Stains & precipitates** - natural or man made mineral/organics deposits (patches, seeps, or gal/minute flow) w/ white, red, orange, yellow, green, blue, indigo, violet, black colors. Red & yellow will be most obvious; but look carefully - some very toxic materials are not obvious.

Where iron pyrite is present, the chemical reaction tends to produce "yellow boy" deposits. Copper stains tend to be bright greens and blues or brilliant luster ruby-red. Other metal stains range from white to black, metallic to dull surface, from opaque to dense. Hydrocarbon chemicals may also be present.

Pay attention to what you are doing; the point is to SAFELY locate sites of possible chemical impacts and get expert help.

How to Review the Photos: Plate D8

D8 UL. Drainage from this mine is direct to the creek. The yellow indicates iron and the chemistry that favors acid generation. This patch is one of several caused by mining (1890s) that still contribute iron rich sediment to the stream from surface erosion.

```
--------------------------------------------------------------
Stains & precptates !  Wh   R   O   Y   G   B   I   V   Blk
  bank or bottom    !                                   none
  color & extent    !  sm-patch-lg  seep  1- 2- 5- 10-  gpm
--------------------------------------------------------------
```

D8 UR. A relative minor seep but you can see the red-orange from the iron chemistry. Below the new rust, there is a darker red stain that extends clear to the bottom of the drainage.

```
--------------------------------------------------------------
Stains & precptates !  Wh   R   O   Y   G   B   I   V   Blk
  bank or bottom    !                                   none
  color & extent    !  sm-patch-lg  seep  1- 2- 5- 10-  gpm
--------------------------------------------------------------
```

D8 LL. This old coal mine near Boulder, Colo, flows about 2 gallons per minute and carries a very high iron concentration of about 30,000 mg/l.

```
--------------------------------------------------------------
Stains & precptates !  Wh   R   O   Y   G   B   I   V   Blk
  bank or bottom    !                                   none
  color & extent    !  sm-patch-lg  seep  1- 2- 5- 10-  gpm
--------------------------------------------------------------
```

D8 LR. This pit connects to the stream through the ground water system. The oil has been sprayed as well as dumped; notice the plastic oil containers.

```
--------------------------------------------------------------
Stains & precptates !  Wh   R   O   Y   G   B   I   V   Blk
  bank or bottom    !                                   none
  color & extent    !  sm-patch-lg  seep  1- 2- 5- 10-  gpm
--------------------------------------------------------------
```

Interpretation for Photo: Plate D8

Site Stains & precptates color (colors from ==	!	Reference (bank or bottom color) Wh none	R iron	O	Y copper	G leads	B	I oil	V	Blk unk-org)
none	!	R								
iron	!	D	R							
copper	!	C	C		R					
leads	!	C	C		C	R				
oil	!	C	C		C	C		R		
unk organics	!	C	C		C	C		C	R	

Examples from the photos::

Pg D8 UL	Ref =	none	[OY]	Aq. Health	= D
D8 UR	" =	iron	[RO]	"	= R
D8 LL	" =	none	[RO]	"	= D
D8 LR	" =	none	[Blk]	"	= C

Site color & extent	!	Reference none	sm-patch-lg		seep	1-	2-	5-	10-gpm
none	!	R							
small patch	!	D	R						
large "	!	I	D	R					
seep	!	P	I	I	R				
1- gpm	!	C	P	P	P	R			
2- gpm	!	C	C	C	C	C	R		
5- gpm	!	C	C	C	C	C	C	R	
10- gpm	!	C	C	C	C	C	C	C	R

Examples from the photos::

Pg D8 UL	Ref =	none	[p.lrg]	Aq. Health	= I
D8 UR	" =	seep	[seep]	"	= R
D8 LL	" =	none	[2gpm]	"	= C
D8 LR	" =	none	[seep]	"	= P

Step 4 Worksheet - Diversity Screen

For each stream, indicate the stream health you would expect and what factor(s) might be the cause or in need of improvement. Look at the totality of what you see; for example, D1 UL, UR, and LL could be judged as follows...

D1 UL: R A D I P C None pools bnk-vege shore instrm-vege chem
Cmts: More bank vegetation would also help create shores.

D1 UR: R A D I P C None pools bnk-vege shore instrm-vege chem
Cmts: Color suggests iron and alot of it.

D1 LL: R A D I P C None pools bnk-vege shore instrm-vege chem
Cmts: A good reference stream. And a nice day.

D2 UL: R A D I P C None pools bnk-vege shore instrm-vege chem

D2 UR: R A D I P C None pools bnk-vege shore instrm-vege chem

D2 LL: R A D I P C None pools bnk-vege shore instrm-vege chem

D2 LR: R A D I P C None pools bnk-vege shore instrm-vege chem

----

D3 UL: R A D I P C None pools bnk-vege shore instrm-vege chem

D3 UR: R A D I P C None pools bnk-vege shore instrm-vege chem

D3 LL: R A D I P C None pools bnk-vege shore instrm-vege chem

D3 LR: R A D I P C None pools bnk-vege shore instrm-vege chem

----

D4 UL: R A D I P C None pools bnk-vege shore instrm-vege chem

D4 UR: R A D I P C None pools bnk-vege shore instrm-vege chem

D4 LL: R A D I P C None pools bnk-vege shore instrm-vege chem

D4 LR: R A D I P C None pools bnk-vege shore instrm-vege chem

----

D5 UL: R A D I P C None pools bnk-vege shore instrm-vege chem

D5 UR: R A D I P C None pools bnk-vege shore instrm-vege chem

D5 LL: R A D I P C None pools bnk-vege shore instrm-vege chem

D5 LR: R A D I P C None pools bnk-vege shore instrm-vege chem

----

D6 UL: R A D I P C None pools bnk-vege shore instrm-vege chem

D6 UR: R A D I P C None pools bnk-vege shore instrm-vege chem

D6 LL: R A D I P C None pools bnk-vege shore instrm-vege chem

D6 LR: R A D I P C None pools bnk-vege shore instrm-vege chem

----

D7 UL:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D7 UR:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D7 LL:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D7 LR:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem

----

D8 UL:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D8 UR:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D8 LL:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
D8 LR:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem

----

Choose some additional stream photos and continue.

______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem
______:	R A D I P C	None	pools	bnk-vege	shore	instrm-vege	chem

With all the detail running around in your head, it is important not to forget the point behind the Diversity Screen. Because we will rarely have a state established standard as a reference (**T-Standard**), you will ordinarily use the Aquatic Life Health Class table to make determinations. As a 'best guess' interpretation, do not fuss over single factors. Look for patterns among the factors that support or confirm a particular Aquatic Life Health determination.

Management Information

Since achieving the Clean Water Act goal of physical, chemical, and biological integrity is a managerial function, the technician needs to provide useful and timely information so that related decisions can be made routinely. The T-Walk advance warning system is intended to be an evaluation and notification to the manager of current and expected stream health, adverse impacts, cost liability for restoration, proposed remedial action, and follow-up monitoring.

>>>> <u>Watershed name and #</u> - local name and agency code (& any sub-wshed #).

The Clean Water Act and cumulative effects as well as State reporting procedures for water quality takes a watershed perspective. Include any official identification of national watershed systems and subwatershed identification. And check for site identifications with legal significance, such as water rights or special use permits.

If a new site id is pending, consider the name and code from a 50 year perspective. For example, UTM coordinates, stream name, trending, and elevation would last, but a simple reference to PC-1 is quickly lost.

>>>> Note site vegetation & management prescription.

It is possible that the 40 acre evaluation cell will include several vegetation types and management prescriptions. The history and existing condition for each type and activity generates its own combination of risks and opportunities. A short summary with special notes about past land use will help estimate the likely outcomes from road construction, rest/rotation grazing, mining, clear cut timber harvest, campgrounds, or similar high impact land uses.

>>>> Make local directions & legal location (1"=2000') accurate enough so later visits are possible.

Monitoring systems are effective if - and only if - they produce specific information on sites that can be re-located and verified. This requires a good written record as well as a series of maps showing exact location. The sequence needs to include a general map of towns, watersheds, and land status; a topog map of roads and trails; an access sketch of trails and landmarks; a site sketch of stream study features with bearing and distances; and a pool map of local dimensions, velocities, and patterns suitable to define future changes.

The essential point is to be able to re-visit a T-Walk site, add to the information, and add the results to the watershed folio. Legal location or the use of UTM's provides a uniform base of location. Adding compass trending and elevation to identified creeks can also furnish good field and map location - as was suggested in Site identification discussion.

>>>> Assessment of Stream Health - compares existing with standard natural conditions. Show existing Stream Health Class and predict Stream Health Class in the next 2 years. Abbreviate health classes as - R robust, A adequate, D diminished, I impaired, P precarious, or C catastrophic.

The overriding objectives for monitoring is to reduce vulnerability to personal liability and litigation, reduce losses to the resource base, reduce restoration costs, and reduce loss of future management options. To be effective, the information needs to be both easily summarized and useful through the entire range of biological conditions. Most important, it has to scale both impact and incremental risk from resource use in terms relevant to management.

The term "resource use" means the interaction of human use with natural impacts including drought, wind, insects, disease, fires, floods, and land slides. There is no special category for these natural events because both planning and policy related to natural resource use has been around long enough to incorporate the risk as well as the magnitude of such events.

The descriptive names for Stream Health Class were chosen carefully: first, to be complimentary to similar concepts in other resource disciplines; second, to serve as a scale of management impacts on stream conditions; and third, to use nomenclature that carries a quickly understood value judgement. Below is a brief description of the transition among Stream Health Classes:

Robust Stream Health suggests that no resource use changes are required; that all systems are in balance; and that natural processes are effectively assimilating management generated effects.

Adequate Stream Health suggests that the resource damage is lawful and within the permitted conditions; that only a few areas are lost to production.

Diminished Stream Health suggests that natural systems are stressed in ways that require resource use to back-off before major damage is done.

Impaired Stream Health suggests that natural systems are clearly pushed too hard; that damage is substantial and recovery will be slow.

Precarious Stream Health suggests that natural systems have been pushed to the limit; that recovery will be very slow and expensive.

Catastrophic Stream Health suggests that natural systems have been pushed beyond their limits and the existing site quality has been destroyed. The management phase is now concerned with failure and liability with substantial resources going to on- and off-site damage control.

Since the Clean Water Act is an accountable managerial function, the Assessment of Stream Health is a key item and reflects a 'bottom-line' measure of how current conditions stack up against the legal goal of ecological integrity. The technical job is to evaluate the existing and expected 2 year Stream Health Class based on descriptions of ecosystem stability, diversity, and production.

>>>> Profile of Noticeable or Expected CWA Impacts - circle existing conditions for each CWA S*T*O*M*P*E*D impacts; show any trends with an arrow. Summarize impact source, i.e. 'badly rutted roads, no waterbars'

For each problem, ecological insults or stressors were identified. The definition used by the team for ecological stressors included any chemical elements or compounds, biological agents, or physical attributes that reduces the ecosystem's ability to maintain itself in a natural condition of niche partitioning and population dynamics.

Many individual stressors were identified. Fortunately, for this purpose they could reasonably be grouped into seven basic dimensions of long term ecological stress. The acrostic "STOMPED" should help you remember the full set as:

S* Sediment regimes in air and water.
T* Temperature regimes in water.
O* Oxidation regimes on land, in air, and in water.
M* Metals contamination of ecological process.
P* Poisoning of ecological process.
E* Equilibrium shifts in geomorphic process.
D* Dissolved chemical regimes in water.

>>>> **Synopsis and necessary response time** - summarize problems; show target date(s) for any emergency action, or remedial work needed to prevent further damage to facilities (including roads) and water courses.

>>>> Expected CWA Restoration Costs - Benefit Lag Time
>>>> Failure to meet CWA responsibilities -- as shown by a Stream Health Assessment (Existing or Expected 2 year) of Diminished, Impaired, Precarious, or Catastrophic -- triggers a stream recovery evaluation for each of the CWA S*T*O*M*P*E*D* impacts that fail the 'Adequate' level. **Benefit Lag Time** measures time-out-of-service for resource development economics until recovery of statutory environmental conditions.

>>>> For the 'with' and 'without' plan condition, develop estimates based on recovery of Robust aquatic life health class and long term productivity.

>>>> Benefit Lag Time - 1) identify activities that aggravate the problem;

Successful watershed plans are developed within the context of natural ecosystem processes and limits; focuses on watershed functions and performance, not symptoms; compares existing conditions with healthy conditions; locates sites of accelerated runoff and erosion; prioritizes high risk situations; and defines management changes necessary to sustain improvements.

Successful watershed projects focus on the whole watershed, treat chronic management problems, emphasize land treatment, and restores dynamic equilibrium to channel shape, slope, and capacity. Successful activities increase ground cover, increase soil water storage, reduce on-site drainage density, and dissipate concentrated runoff.

>>>> ... 2) estimate recovery (years) for S*T*O*M*P*E*D Impacts.

>>>> Guidelines:

>>>> **S* Rcvry,** yr = Storm Runoff Control + Bank Stability + Sediment Flush

T-Walk uses storm runoff control and bank stability to provide field documentation of results of land stewardship. Both measure the impact of long term land management strategies. Both can be used to show both direct on-site effects as well as indirect watershed effects.

The time it takes for a stream to flush excess sand through a given reach identifies a rate of change in cumulative effects. There are natural differences in stream power and bed materials; consequently, some reaches are more susceptible to sediment damage than others. The ability to flush sediment reflects several stream physical processes that can be used in project design to help restore stream equilibrium and avoid sediment related cumulative effects.

>>>> - Storm Runoff Control = the greatest time for a,b, or c where
a = LFH ground cover recovery, (use LFH G. Cover Recovery Table);
b = road erosion control, (use R. Erosion Recovery Table);
c = gully & rill stability, (best guess or LFH G.Cover Recvry Table).

The time it takes for site erosion, road erosion, and gully erosion to slow to acceptable rates are expected to be concurrent events. The main exception is the contribution of roads or open sites that aggravate rill and gully problems; these sites have to be fixed first, then the rills and gullies.

Storm runoff control combines several phases of Best Management Practices as contained in regulation or specified by land use plans. It's basic purpose is erosion control, road erosion control, and gully erosion control.

T-Walk uses LFH depth as a measure of site recovery potential and % ground cover as a measure of land use. Note, first, the general pattern that recovery is slower if conditions start with either poor sites or large amounts of bare soil; and second, recovery is often measured in decades and half- and whole centuries.

LFH Ground Cover Recovery, Years*

LFH depth'	<20	20	30	40	50	60	70-99%
	Ground Cover %						
0.01	106	54	35	19	8	2	0
0.05	92	47	30	17	7	2	0
0.1	78	40	26	14	6	2	0
0.2	55	28	18	10	4	1	0
0.3	38	20	13	7	3	1	0
0.4	27	14	9	5	2	1	0
0.5	19	10	6	3	2	0	0
0.6	13	7	4	2	1	0	0
0.7	9	5	3	2	1	0	0
0.8	7	3	2	1	1	0	0
0.9	5	2	2	1	0	0	0
1.0	3	2	1	1	0	0	0

* LFH Ground cover recovery, yr = (110 * e^-3.5*LFH) * (1 - 2X + X^2)
where LFH = litter, fermented and humus depth (ft)
X = (Grnd Cvr%/70); if 70% or more, Recvry = 0 yr.
(detrimentally compacted areas are not Grnd Cvr).
Ex: 80% bare soil; undisturbed LFH of 0.5' (6" duff). Rcvry = 10 years

Refresh your memory regarding ground cover (page 8-16) and review Plates L1 - L4 again. Then for the following list, estimate recovery time.

Site	Soils Photo Pair		Litter Depth'	LFH Depth'	Topsoil Depth'	Ground Cover%	Recovery Table, Yrs
L1	415	416	0.01	0.15	0.9	if 40% then?	12 yr
L1	450	451	0.02	0.11	0.6	if 30% then?	25 yr
L1	456	457	0.02	0.11	1.6	if 60% then?	2 yr
L2	413	414	0.07	0.12	0.4	if 50% then?	6 yr
L2	442	441	0.06	0.07	0.4	if 20% then?	45 yr
L2	487	486	0.12	0.2	0.5	if 20% then?	28 yr
L3	489	488	0.05	0.12	0.25	if 30% then?	25 yr
L3	498	497	0.08	0.18	0.9	if 30% then?	19 yr
L3	502	501	0.05	0.08	0.6	if 50% then?	6 yr
L4	920501.9		0.06	0.25	1.0	if 50% then?	3 yr

Logged in 1965; it has taken nearly 30 years to get to this point.

L4	920519.18-20		0.00	0.05	0.4	if 30% then?	30 yr
L4	920519.18-20		0.00	0.05	0.4	if 50% then?	7 yr

Road Erosion Recovery, Years*

Sediment Yield%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	1	1	1	2	2	2	3	3	3	3	5
2	2	3	5	6	8	9	11	12	14	15	22
5	4	7	10	13	16	19	22	25	28	31	46
10	5	9	13	17	22	26	30	34	38	43	64
15	5	10	15	20	25	30	35	40	45	49	74
20	6	11	17	22	27	33	38	44	49	54	81
25	6	12	18	24	29	35	41	47	52	58	87
33	7	13	19	25	32	38	44	50	57	63	94
50	7	14	21	28	35	42	49	56	63	70	105
67	8	15	23	30	38	45	53	60	67	75	112
85	8	16	24	32	40	48	55	63	71	79	118
90	8	16	24	32	40	48	56	64	72	80	120
95	9	17	25	33	41	49	57	65	73	81	121
99	9	17	25	33	41	49	57	65	73	81	121

* Recvry to annual 0.3 cf/a; ln(0.3/(0.4Syld%^1.7)*TransTime. Where:
Syld% = sediment yield to stream, %.
TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.
Ex: Vege buffer 85% effective, 3 year erosion contrl plan. Rcvry = 15 yr.

The CWA S 404 exemption for roads requires installing BMPs including sediment buffers and erosion control:

- ... shall be located sufficiently far from streams ...
- ... shall be stabilized ... to prevent erosion; ....

This table looks at the trade-off between road location to maximize the value of buffers in preventing stream damage and the increased erosion control efforts needed in places where buffers are not enough to protect the stream.

Exercise

1) T-Walk does not define "effective erosion control"; this is dependent on standards and guidelines that pertain to authorized local land plans. Normally the plan includes requirements on ground cover recovery, temporary and permanent erosion or sediment control measurements, and maintenance operations. Write a short summary of the "effective erosion control" for the area you work in.

2) What combinations of sediment yield% and transition time would be within:
a 2 year recovery time?
a 5 year recovery time?

>>>> Bank Stability = Extra time as needed for stability after Storm Runoff Control recovery. Extra time is likely for sediment or flow equilibrium shifts, such as sediment spills, water yield increases, or changes in stream flow peak or bankfull duration. Otherwise, assume no extra bank stability recovery is needed.

Bank stability is dependent on watershed conditions. If bank stability problems are localized and not the result of upstream conditions, land use activities designed for good storm runoff control conditions on-site will also provide localized bank stability. If stability problems occur because of accelerated sedimentation or flow, then natural recovery will be greatly delayed and will likely require bank toe hardening along with revegetation.

>>>> - Sediment Flush = If Storm Runoff Control &/or Bank Stability need recovery time, then add Sediment Flush to the total. Otherwise, it reflects recovery time from a single massive sediment spill.

Sediment flush reflects the time it takes for the stream to move the excess sand through the system and return the stream bed to natural conditions. Upon occasion, sediment flush is perceived as a way for the stream to recover from excess sediment. This is true for stream reaches that have sufficient energy; but since sand does not evaporate, it remains in the system as a public problem. This is the heart of the sediment related cumulative effects issue.

T-Walk takes the perspective that flushing may move the problem, but the basic responsibility remains the same. T-Walk calculates the time it takes to move sand through a given system; the value is to concentrate restoration efforts where natural processes will help reduce costs or speed recovery. The objective is to remove excess sediments, rather than let them go down stream.

>>>>> Sed Flush Rcvry, yr = 18 / (Grd * Cmp) where:
Grd % = stream gradient,%, (range 0.5% to 10%);
Cmp = Competency of Bank Matrls & Assc. Vege; (see Tbl)

Ex: 20% LFH g.cvr, 0.3'LFH, 90% effect. buffer, 2yr road eros ctrl plan.
No active gullies; 2% stream grade; Glacial cobble w/ shrub.
Stm RO Cntrl = greater of LFH g.cvr =20, road = 9, or gully = 0
S* Rcvry = (SRC= 20) + (BS= 0) + (SF= 11) = 31 years

This formulation combines a very simplistic view of the stream energy and the competency of stream bank material and vegetation to resist erosion. Sediment flush time decreases with steeper stream gradients and tough, hold-it-together, stream banks. There are 3 reasons for continued use of the formula: nothing else is yet available in the T-Walk context, the answers have been useful to the restoration question, and there is no need yet to get better answers.

Competency* of Bank Materials and Associated Vegetation

Bankland Regime	Raw	Grs	Brs	Trs	Bankland Regime	Raw	Grs	Brs	Trs
Gb	.80	.87	.91	.94	Rr	.89	.94	1.00	.99
Gc	.69	.75	.79	.81	Rb	.86	.91	.96	.96
Gg	.50	.56	.65	.62	Rc	.69	.76	.84	.85
Lf	.27	.33	.45	-	Rg	.48	.55	.66	.67
Jf	.31	.38	.40	-	Rs	.23	.31	.38	.40
Mb	.70	.74	.83	.81	Rf	.24	.31	.41	.43
Mc	.54	.60	.69	.66	Tc	.55	.64	.75	.77
Mg	.37	.46	.54	.53	Tg	.40	.52	.63	.65
Ms	.17	.27	.31	.33	Ts	.19	.28	.37	.40
					Tf	.21	.30	.38	.40

* Rr (Resid bedrock well fractured, colluvial soils) with good brush cover had greatest competency (C=1); all other Bankland Regimes were compared to Rr brush.
G = Glacial; L = Lake; J = jackstraw (like a filled in beaver dam);
M = mass movement deposits; R = Residual materials; T = Terrace deposits.
See channel material size codes for r, b, c, g, s, f.
Ex: terrace deposits of cobble covered with willow shows competence of 0.75

The "Competency ... " table values show more accuracy (.xx) than they should. Round to nearest 0.1 and keep in mind that it takes substantially more time for a sediment flush in streams with highly erodible bank material than it does for those with protected banks.

Recall that the "18/(stream grade * competency value)" is for an individual sediment spill and not for how long it takes a bank condition to improve.

Review Photos

```
B1 UL would you agree that Competency is:  Rb Trs = 1.0?     yes  no
B1 UR   "    "    "     "      "       ":  Tg Grs = 0.5?     yes  no
B1 LL   "    "    "     "      "       ":  Rs Raw = 0.2?     yes  no
B1 LR   "    "    "     "      "       ":  Rr Grs = 0.9?     yes  no

B2 UL   "    "    "     "      "       ":  Tg raw = 0.4?     yes  no
B2 UM   "    "    "     "      "       ":  Rb Brs = 1.0?     yes  no
B2 UR   "    "    "     "      "       ":  Tg Trs = 0.6?     yes  no
B2 LL   "    "    "     "      "       ":  Rc Brs = 0.8?     yes  no
B2 LR   "    "    "     "      "       ":  Rb Brs = 1.0      yes  no

B3 UL   "    "    "     "      "       ":  Gc Raw = 0.7?     yes  no
B3 UM   "    "    "     "      "       ":  Gg Raw = 0.5?     yes  no
B3 UR   "    "    "     "      "       ":  Tg Raw = 0.4?     yes  no
B3 LL   "    "    "     "      "       ":  Ts Grs = 0.3?     yes  no
B3 LR   "    "    "     "      "       ":  LWD    = 0.9?     yes  no
```

>>>> **T* Rcvry**, yr = use best guess on temp recovery; no data.

>>>> **O* Rcvry**, yr = 1 year recovery after BOD source control; no data

>>>> **M* Rcvry**, yr = 20 year ion release after source control; no data

>>>> **P* Rcvry**, yr = 1 year recovery after source control; no data

>>>> **E* Rcvry**, yr = Q & Sed shifts are long term; no data

Watershed equilibrium is a time-independent steady state that just transmits the runoff and debris characteristically produced under the controlling climatic regime. Stream water and sediment discharge, with associated channel material, slope, width, depth, and cross-sectional area characteristics, are clearly interrelated with basin size, shape, relief, and stream order.

If protective vegetation is removed, the surface shows a sharp increase in both runoff intensity and erosion susceptibility. The watershed responds with increased drainage density, increased channel gradients, and decreased local relief. Areas with new rill and gully development cross a response threshold, or discontinuity, which leads to a much drier soil water economy.

Exercise

Geomorphologists have periodically used limits on watershed disturbance as an indication of the risk of channel blowout. Depending on the geology, limits that appear to be "safe" have ranged from 15% to 30% in disturbed area.

Referring to map and photo examples (page 8-5+), and considering the entire example, mark the limits that you would expect to be exceeded:

Map A	limits	15	20	25	30
Map B	limits	15	20	25	30
Map C	limits	15	20	25	30
Photo D	limits	15	20	25	30
Photo E	limits	15	20	25	30

What is the effect of CDA on accelerating peak flows?

What is the effect of fire on accelerating peak flows?

>>>> **D* Rcvry**, yr = 1 year recovery after source control; no data

>>>> Expected CWA Restoration Costs -- Physical Restoration Costs $1000

These costs reflect damage for which there is both responsibility and liability. The costs are developed as a measure of the legal liability to restore stream health, but do not include land treatment or naturally caused stream damage for which there is no liability under the Clean Water Act. (The actual land and stream treatments, schedules, and costs are in the Remedial Action Plan.)

>>>> Sediment related restoration - the problem with sand is the major loss of aquatic insect production & loss of pool depth for overwintering fish. Actual sand removal -- compared to in-channel redistribution using structures -- seems to be the most cost effective and risk free intrusion into the natural system.

How much restoration is necessary is determined from the Thalweg Standard and the recovery goal of both pool depth and Tarzwell Substrate Ratio. The basic T-Walk recommendation is to remove the sand from the stream rather than build structures for pools or to flush the substrates. The first point is to correct the problem rather than move it downstream. The second point is that stream structures often interfere with bankfull stream flow dynamics and create induced sediment deposition and additional bank erosion.

>>>> "**S*SWEEP**" Costs = sand cleaning by area to T-std productivity.
>>>> **S*SWEEP $** = Impact Area, sf x sweeper$. Where:
ImpactArea = stream area of bankfull width x impact length, sqft.
sweeper $ = suction drdg, 25hp, ATV, <10' lift $0.12/sqft
>>>> "**S*SCOOP**" Costs = volume related; sand removal from sites <5' deep.
>>>> **S*SCOOP $** = Cubic Yard x scooper $ Where:
Cubic Yard = volume of deposits to be lifted.
scooper $ = basin, backhoe, haul - $8-10/cy
= backwater, backhoe, haul $5-8/cy
= suction drdg, 60hp, roadside, <30' lift - $8-10/cy
= suction drdg, 25hp, ATV, <20' lift - $15/cy
= suction drdg, 8hp, hand, >20' lift - $60/cy
Ex: Stream Bcs1Tc, 21'x3000' impact; SWEEP $ = 63,000 x $0.12 = $7560.
Ex: Stream Abs15Rb, 100 cubyd spill in 7 pools. SCOOP $ = $6000.

<u>Exercise</u>:

1) A 20' wide cobble bedded stream has heavy sedimentation with a TSR = 15. For 2000' of impacted channel, would S*SWEEP $ = $4800? yes/no

2) After 25 years of logging road erosion and fill failure, a 20' wide cobble bedded stream currently has 60% sediment damage over 6 miles. If the material is removed with a suction dredge, would S*SWEEP costs = $46000? yes/no

----

>>>> Predicting stream clean-up costs from road erosion depends on stream character and Road Erosion Material Yield to the stream (REMY - see Table).

>>>> Use the larger of either **S*SWEEP $** or **S*SCOOP $** for clean up:

Road S*SWEEP $ = RoadAc x REMY x (152/T-std TSR) x sweeper $

Road S*SCOOP $ = RoadAc x REMY/27 x scooper $

Ex: $202 clean up for 44x1200' road, 20% sedmnt yield, 4yr erosion control plan. T-std TSR is 32; clean up w/ 25hp suction dredge.

Road S*SWEEP $ = 1.21 road ac x 293 x (152/32) x 0.12 = $202

Road S*SCOOP $ = 1.21 " " x 293/27 x 15 = $197

Most erosion control efforts tend to be minimal. The T-Walk perspective is that road erosion control is necessary for Robust Stream Health. The purpose here is to balance out both sides of the erosion control versus stream recovery issue. Of the 4 factors used by T-Walk, 3 relate to management choices: the capacity of the buffer and expedient traps, the time it takes to establish erosion control, and the amount of road prism contributing sediments. These factors are summarized in the "Road Erosion Material Yield to Stream" table as "Sediment Yield %" and "Transition Time to Effective Erosion Control." The tabular values are totals of annual amounts of erosion that exceed 0.3 cubic foot per road acre. The 0.3 cubic foot limit is a researched value achieved using normal Best Management Practices on timber sale main haul roads in Deadhorse Creek, Fraser Experimental Forest near Fraser, Colorado.

The 4th T-Walk factor uses Tarzwell Substrate Ratio as an index of how much stream bottom has to be cleaned per cubic foot of sediment delivered. For example, a cubic foot of sand will damage about 16 square feet of fine gravels (TSR=9), but only 3 square feet of large cobble (TSR=50).

Both S*Sweep and S*Scoop costs are calculated; the larger of these costs can then be compared for alternatives with different road location, road drainage, or erosion control plans. Current field experience suggests that the vote should go in favor of erosion control; it is about 20 times more expensive to take material out of stream than to keep it on-site.

Road Erosion Material Yield to Stream, cub ft/road acre*

Sedmnt Yld%	Transition Time to Effective Erosion Control, yr 1	2	3	4	5	6	7	8	9	10	15
1	0.4	0.4	0.4	0.7	0.7	0.7	1.0	1.1	1.1	1.1	1.8
2	1.8	2.6	3.7	4.6	5.8	6.6	7.7	8.5	9.6	10.7	15.4
5	9.6	15.2	21	27	33	38	44	50	56	62	91
10	32	50	70	89	109	129	149	168	188	208	306
15	63	101	140	179	219	258	298	338	377	416	615
20	103	165	229	293	358	422	487	552	617	682	1006
25	150	241	335	429	523	618	713	808	902	997	1471
33	241	387	537	688	840	992	1144	1296	1448	1600	2361
50	489	785	1090	1397	1704	2013	2321	2629	2938	3246	4790
67	804	1292	1793	2298	2804	3311	3819	4326	4834	5342	7882
85	1205	1936	2688	3445	4203	4963	5723	6484	7246	8006	11814
90	1328	2134	2963	3797	4632	5470	6308	7146	7985	8824	13020
95	1457	2340	3248	4162	5079	5997	6916	7835	8754	9674	14274
99	1562	2510	3484	4464	5448	6432	7418	8404	9390	10376	15311

* Cumulative sum of annual road erosion material yielded to a stream starting from initial disturbance and ending with yields less than 0.3 cuft/road ac:
Tot Road mtrl, cf/a = SUM [0.4Syld%^1.7 * e^-(yr/TransTime)] Where:
Syld% = sediment yield to stream, %; f(buffers & expedient traps).
TransTime = lapse time from initial disturbance to effective erosion control & road bank stability, years.
Ex: Vege buffer 85% effective, 3 year erosion contrl plan, 1024' drain x 45' exposed width. Road mtrl, total cf = (1024x45/43560) x 140 = 148 cf
Same road, 10 yr stability (no erosion plan): (1.06) x 416 = 441 tot cf
Same road, 33% buffer, 10 yr stablty: (1.06) x 5342 cf/a = 5663 tot cf

The "Road Erosion Recovery, Years," previously mentioned, and this one, "Road Erosion Material Yield to Stream, cub ft/road acre," are structured to look at trade-offs between the erosion control BMP and the one for sediment buffers. The table shows expected sediment quantities in the stream system, as a function of sediment yield through the buffer and scheduled erosion control. The planner may then compare the relative costs of several alternatives that achieve the "no impairment" standard. The table can be used in 4 basic ways:

1) to test various locations versus costs for erosion control;
2) to identify likely long term effects for stream restoration costs;
3) to estimate the time and volume needed for expedient sediment traps; and
4) to see if the "no impairment" conditions is likely to be met.

For the 4 items, compare Roads AA, BB, and CC and total costs. (8 acres/mile). Meet the "no impairment" standard; assume $10/cubic yard for expedient traps.

AA -- $20,000; 15% sediment yield; 7 years transition time. ______$

BB -- $24,000; 15% sediment yield; 1 years transition time. ______$

CC -- $18,000; 50% sediment yield; 7 years transition time. ______$

How to review the photos

These photos show some examples of roads and the interaction with the stream. Look at the photos in detail, then answer the questions. Questions about BMP's come from this short list:

BMP 1 limit road & trail system ...
BMP 2 buffers for roads and trails ...
BMP 4 erosion control ...
BMP 5 stay out of "waters" ...
BMP 6 minimize vegetative disturbance in "waters" ...
BMP 10 avoid discharges into ... special aquatic sites ...

Plate R1 shows a major transportation link built about 15 years ago.

R1 UL section is comparable to the worst 20% for the total road in grade and construction. The ditch, with constant pulling for maintenance, has not stabilized anywhere on this road; erosion is particularly severe on grades over 6% (which are common).

R1 UR. This is a draw, not a road, just off the saddle that receives ditch water and sediment from an 1100' segment of 6% road.

R1 LL. Same draw, 150' downstream. The log is holding some sediments in place. Another 200' downstream, the draw intersects another road, below which it becomes perennial flow.

R1 LR. Draw is tributary to this 20' wide, gravel-cobble bedded stream. The stream, heavily impacted with sand sedimentation, should have a reference condition (T-Std) TSR = 32.

1) Assuming the road disturbance is 1 acre, would you agree:
   - that Sed Yld% is 99%? yes no
   - that "effective erosion control" is at least 15 years? yes no
   - that REMY is at least 15,000 cubic feet? yes no

2) Is the draw (UR & LL) "waters of the U.S."? yes no

3) Calculate LR CWA liability (20') for S*SWEEP cost (per mile) ______$

4) Write a short summary: How well are these BMP's being addressed?

BMP 1 limit road & trail system ...
BMP 2 buffers for roads and trails ...
BMP 4 erosion control ...
BMP 5 stay out of "waters" ...
BMP 6 minimize vegetative disturbance in "waters" ...
BMP 10 avoid discharges into ... special aquatic sites ...

Plate R2 shows past and present effects in a conifer logged watershed.

R2 UL shows a logged basin; watershed geomorphic criteria such as an upper limit of 30% in the watershed has not been exceeded. The road and skid trail system is extensive; most lower slopes were logged about 1900.

R2 UR is an example of a typical skid trail from that early logging. All recent logging has used the same skid trail system, but made no discernible investment in water bars, erosion control, or use of buffers. Although this skid trail is on a gentle grade, erosion has been extensive.

R2 LL shows heavy sedimentation in a logging debris laden stream. The woody debris is old, but the photo shows bright chroma sands that indicate continuing erosion from the road system. There has also been major and continuing loss in pool depth and volume and in macroinvertebrate habitat.

R2 LR is a downstream view showing general condition of stream structure, woody debris, and pool configuration. Even though much of this is "old" debris, the sedimentation from the road system is current.

1) If 1/3 of the 20' wide channel is cobble riffle (TSR = 50) and 2/3 are pools with an average of 1.5' deposition (averages 8 cubic feet of material per foot of channel reach that are in pool structures). Per mile of stream, what would you expect the CWA S*SWEEP and S*SCOOP costs to be?

- with the suction dredge, the S*SWEEP cost is = ? ________$

- with the suction dredge, the S*SCOOP cost is = ? ________$

2) Write short summary: How well are these BMP's being addressed?

BMP 1 limit road & trail system ...
BMP 2 buffers for roads and trails ...
BMP 4 erosion control ...
BMP 5 stay out of "waters" ...
BMP 6 minimize vegetative disturbance in "waters" ...
BMP 10 avoid discharges into ... special aquatic sites ...

Plate R3 shows a minor haul road and skidding in draw bottoms.

R3 UL shows why water bars don't work. The road is not closed to traffic and wheel ruts are known to be major reasons for water bar failure. Even without that failure, the water bar is located at an existing water course, so any sediment generated on the road will immediately travel to the water course without the benefit of a sediment buffer.

R3 UR shows an area recently logged with all skidding down hill to the main road. Note the concentration of trails into and down the draw.

R3 LL shows a recent skid trail down a draw bottom leading to a road side landing. Soils have been compacted and gouged, thus setting the stage for accelerated erosion during high intensity rain storms. A perennial stream is just on the other side of the road.

R3 LR shows a typical low gradient stream with sand depositions. The light color and relatively bright chroma are good indicators of recent erosion.

1) For R3 UL, how much time do you think it will take for "effective erosion control"? for R3 UR and LL?

2) If protected areas retain an LFH depth of 0.4', how long do you think it will take the bare areas to recover?

3) For R3 LR, what do you think the TSR is? If this was originally a typical gravel-cobble stream (TSR = 32), what is the CWA liability (S*SWEEP) per mile?

4) Write short summary: How well are these BMP's being addressed?

BMP 1 limit road & trail system ...
BMP 2 buffers for roads and trails ...
BMP 4 erosion control ...
BMP 5 stay out of "waters" ...
BMP 6 minimize vegetative disturbance in "waters" ...
BMP 10 avoid discharges into ... special aquatic sites ...

Plate R4 shows new main road construction.

R4 UL shows last summer & fall construction, built without temporary erosion control or sediment control measures. As of April, there is no evidence of revegetation or steps taken to insure revegetation. The inside ditch grade is 4% and collects water for 1000'.

R4 UR shows a continuation of the ditch cut through the grass to within a few feet of a stream.

R4 LL shows direct stream sedimentation from the ditch.

R4 LR shows typical stream of large gravel & small cobble leading into an 80 year old channel change.

1) Assuming that good soil and easy topography would result in the "effective erosion control" standard being meet in 3 years through entirely natural processes, what could have been done to protect the stream during this period?

2) Now given the deposition from this one 1000' section of road (say 1 acre), and damage to 800' of stream (R4 LR), what is the CWA liability?

3) Would you agree that protecting the stream at this point would have been easy -- with either buffer and/or sediment pit? And stream damage needless?

4) Write short summary: How well are these BMP's being addressed?

- BMP 1 limit road & trail system ...
- BMP 2 buffers for roads and trails ...
- BMP 4 erosion control ...
- BMP 5 stay out of "waters" ...
- BMP 6 minimize vegetative disturbance in "waters" ...
- BMP 10 avoid discharges into ... special aquatic sites ...

Plate R5 shows a transportation system built over 30 years ago in steep and erosive topography. Photos taken in 1961.

R5 UL shows a combination of cats and cable equipment. The cat on the ridge line is a mobil spar. After the trees are cut and skidded down to the road, the cables are re-wound, the cat moves to a new ridge position, and the cable re-strung. The cable is not high enough to get the logs off the ground. In order to support the equipment, the roads are full bench.

R5 UC shows one part of a fire salvage sale that removed all trees including live trees of commercial size. Below the main haul road (camera point), there are 4 temporary roads to be used by a jammer to skid the logs up hill. The bottom road was also used to receive cat-skid material from the facing slope that could not be reached by the jammer. Logs above the road were cat skidded to the road. Where it was particularly steep, the cats would walk the ridge and turn straight down to collect the logs, then follow the skid trail down to the main road. To keep the main road in service, the road was bladed off periodically during the day.

R5 UR. Meetings about resource conditions were common; this 1961 photo shows FS managers and staff from Washington, the Region, the Forest, the District, and the Research Station. The problem was economics; because the granite soil lacked clay, it was cheaper to build a full bench road than to compact and stablize a balanced cut and fill road. And it was cheaper to side cast all material rather than end-haul to better locations.

Road widths in steep topography are extended because of the large equipment, the decision to side cast all material, and the need for wide turns. Notice the high cut banks above the vehicles.

R5 LL shows a typical in-place road system before logging has started. All roads are full-bench with material side-casted.

R5 LR shows the combination of a rain storm on large amounts of side cast material. In this case, from one road to the next.

1) How many years will it take for "effective erosion control"? _______$

2) What downstream effects would you expect to find after a 4" storm?

3) What is CWA S*SWEEP cost per mile for 60' wide river? _______$

4) Assuming adequate funds to reach "effective erosion control" in 6 years, what could have been done to protect the stream during this period?

5) At a resource allocation and planning level for this topography and geology, protecting streams is tough. What strategies/methods would you use?

6) Write short summary: How well are the road BMP's being addressed?
limit road & trail system; buffers for roads and trails; erosion control; stay out of "waters"; minimize vegetative disturbance; avoid discharges;

>>>> Expected CWA Restoration Costs - Chemical Restoration Costs $1000
>>>> Cost data for restoration has not been worked up; go w/ your best guess.

No question about the importance of this subject. Nor does there seem to be any answers short of detailed studies and full understanding of the complexity that spans politics and economics as well as environmental science. Current field experience suggests that restoration projects will be difficult, expensive, lengthy, and potentially full of litigation.

In the advance warning context, T-Walk can be used to flag developing situations and help narrow the list of sample sites needed for chemical analysis. However, hazardous materials is well beyond T-Walk; for you to be safe and still respond properly follow the emergency response prodcedures set up by the State and EPA.

>>>> Reviewer & date passed to authority - water quality is the manager's responsibility; your job is to pass along the right information.
>>>> ==
>>>> Reviewer & date passed to authority:

>>>> ==

While management is ultimately responsible for clean water, the advice is only as good as the technician's commitment to a good job. The signature is a part of the feed back loop that has to be fast, friendly, and formal.

>>>> <u>Remedial plan</u> - defines the watershed treatment plan and implementation schedule. Identify remedial **Objectives** and the completion target date necessary to prevent more damage.

>>>> Identify specific **Sponsors/clientele** currently affected by the situation and the **values to be protected**. Identify any special or targeted plant or animal species.

>>>> **Work items** - show what & how much has to be done; use the abbreviated list for common channel, road, revegetation, and expedient (temporary) sediment or erosion control measures. Figure necessary costs & special skills. Then add name and telephone of the planner for later questions.

>>>> Some Regional unit costs - to be applied with care!

		$ low -	high
Clow	Low flow channel structures for sediment contrl, ea	1100	3600
Cnew	Channel construction new/enlarge, cubic yard	15ave	
Crem	Channel debris/sediment removal, $50/lrg woody debris	10/cy ave	
Cstb	Channel/shore bank material stability, cy riprap	10	25 w/revege
Ebsn	Expedient sediment/debris basin, cy	10 ave	
Ecut	Expedient in-channel trap (trench or trough); no dam	10/cy ave	
Edam	Expedient siphon dam (slant or 'T' pipe), dam	700/<10' high	
Ediv	Expedient storm runoff diversion, linft	100 ave	
Efil	Expedient filter/sorbent material fence, linft	10 ave	
Efur	Expedient log & furrow erosion barriers, cy	12	17
Epit	Expedient small sediment catch 'pit', cy	0	10
Erow	Expedient slash/brush windrow, linft	0	3
Rbar	Water bar, roll dip, & other cross drain repair, ea	25	
Rcul	Bridge & culvert stabilization, ea	500	
Rdrn	Road, trail, & corridor drain ditch stabilztn, linft	0.5	
Rrem	Road, trail, & corridor removal & revegetation, ac	1000	3100
Rstb	Road fill & bank stability, sqft	1	
Vbfr	Permanent vegetation buffer for sedmnt cntrl, linft	0	0.2
Vcvr	Vege cover density for on-site erosion cntrl, sqft	.1	1
Vexc	Vege protect by livestock exclusion, mi	elect= 500,	barb= 3000

Make a clear plan and a schedule the work items. Concentrate your first actions on disconnecting sediment source areas from the stream system and on trapping excess sediments already in the system. If you have to spend hard dollars, then start at the top of the watershed and work down; however, use any opportunity to disconnect sediment source areas whenever and wherever you can.

Channel traps are holes or trenches excavated in the channel and designed for sediment control. The traps can be used as a preventative measure, as on new construction, or for existing problems where stream power will help concentrate sediment and reduce the overall costs of stream recovery. But do not build dams or add fill material to create the sediment trap; these features are not covered by the S404 exemption criteria and create future maintenance obligations that a "hole" does not. Make sure the excavated material is stabilized and outside the expected flood stage. These Nationwide Permits (33 CFR 320ff) may also apply:

- NWP #16 "Return water from upland contained disposal areas";
- NWP #27 "Wetland and riparian restoration and creation activities";
- NWP #33 "Temporary construction, access and dewatering";
- NWP #37 "Emergency Watershed protection and rehabilitation".

What is essential is to stay focused on the stream health objective and make sure there is a payoff to each effort. This may be very difficult; if there is money to spend, people will be there with pet projects or different objectives. But, unless the project stays focused, not much will actually get done.

Remedial action needs to plan the long term including the changes in land use that are causal factors. Features and methods can be pieced together to make an economical plan based on what problems need to be solved first before working on the follow-up steps. This is the purpose of CWA S319 and it will take decades.

However, if you are boss-for-the-day, make sure there is a payoff. This is not particularly difficult; there are many, many sites where even minor work will help natural recovery processes get started and have major benefit. Look for the ways to fit pieces together into a common sense and economical remedial plan that will achieve and maintain stream health over as many miles as feasible. To do this means making the most use of the least expensive techniques and looking for long term results. Current experience suggests:

-- For conditions vulnerable to land use, install only those features that can be supported and enforced with management that is part of the budget.
-- Favor installing features that will not be nullified by later action or the failure of management to enforce requirements.
-- Use methods that are self maintaining and of low vulnerability.
-- Do not install features that can not or will not be protected.
-- Schedule the installation to focus on the most limiting factors first.
-- Do not spend resources on treatments that have no definable result.
-- Avoid features that require long-term, high-cost maintenance obligations.
-- Avoid methods that depend on high levels of administration.

DESIGN CRITERIA

This section has two parts. The first is organized in the order that remedial measures show up in the field manual. The second part is a photograph review, starting with the simplest and least expensive measures and progressing to the more complex and higher price tags.

>>>>	Clow	Low flow channel structures for sediment contrl, ea	1100	3600
>>>>	Cnew	Channel construction new/enlarge, cubic yard	15ave	
>>>>	Crem	Channel debris/sediment removal, $50/lrg woody debris	10/cy ave	
>>>>	Cstb	Channel/shore bank material stability, cy riprap	10	25 w/revege
>>>>	Ebsn	Expedient sediment/debris basin, cy	10 ave	
>>>>	Ecut	Expedient in-channel trap (trench or trough); no dam	10/cy ave	
>>>>	Edam	Expedient siphon dam (slant or 'T' pipe), dam	700/<10' high	
>>>>	Ediv	Expedient storm runoff diversion, linft	100 ave	
>>>>	Efil	Expedient filter/sorbent material fence, linft	10 ave	
>>>>	Efur	Expedient log & furrow erosion barriers, cy	12	17
>>>>	Epit	Expedient small sediment catch 'pit', cy	0	10
>>>>	Erow	Expedient slash/brush windrow, linft	0	3
>>>>	Rbar	Water bar, roll dip, & other cross drain repair, ea	25	
>>>>	Rcul	Bridge & culvert stabilization, ea	500	
>>>>	Rdrn	Road, trail, & corridor drain ditch stabilztn, linft	0.5	

Objective: No material developed.
Project Area Map:
Worksheet: References:

>>>> Rrem Road, trail, & corridor removal & revegetation, ac 1000 3100

Objective: Adequate and timely revegetation on disturbed areas that are to be returned to permanent vegetative cover. Treatment is designed for disturbed areas, such as roads and trails, that no longer meet management requirements or continue to be at-risk for the stream system. Once vegetation is reestablished, there will be little or no erosion risk.

Equipment: Motor graders fitted with adjustable ripper teeth are good choices for 2-track roads that have vegetation in the center. If compaction is deep and extensive, the subsoiler may be a better choice than a single ripper tooth.

Project Area Map: Based on surveys of soil compaction, infiltration rates, and cover conditions, determine areas suitable for the following treatments:

Roughen -- Soil density and infiltration rates are suitable for adequate and timely revegetation. Roughened surface condition, slope, and expected storm flow are low enough to have minimal rill erosion risk.

Rip -- Soil and infiltration conditions are such that 1-pass ripping or subsoiling is needed to provide a seedbed for adequate and timely revegetation. Rip patterns, slope, and expected storm flow are low enough to have minimal rill erosion risk.

Rip and Spread -- Soil and infiltration conditions are such that a 2-pass rip and spread is necessary to provide an adequate seedbed for timely revegetation. A 1-pass rip will generate enough erosion hazard from the exposed rip channels to make the 2nd pass to smooth out the rip channels worthwhile. But the risk from surface wash on the smoothed bare soil is sufficiently low that a temporary lining or cover is not necessary.

Temporary Lining -- For locations where surface condition, slope, and minor storms generate sufficient energy to make erosion control with temporary erosion lining or matting worthwhile. This can be the last step for either the "roughen" or "rip and spread" operation.

Mechanical Stability -- For conditions where vegetation can not fully stabilize the site and some form of mechanical support, such as drop structures, are necessary to insure stability.

Worksheet:

1. Abbreviations:

BlkDn = soil bulk density, g/cc.
CDA = Connected Disturbed Area, acres.
Qpk = expected peak for 10yr 24hour design storm, cfs.
Q__ = acceptable peak flow for treated condition, cfs; where:

- Qline = temporary lining for concentrated storm flow.
- Qnow = current condition; value = 0 for active erosion.
- Qrip = ripped with continuous downslope grooves.
- Qruff = roughened with no downslope grooves.
- Qsprd = rip and spread or subsoiled; no downslope grooves.
- Qvege = fully vegetated ecosystem condition.

2. Map and field work -- steps

A. Map individual CDA units selected for complete revegetation.

B. Determine acres for each CDA unit above its most erosive outlet. For each CDA unit:
- .. determine the slopes (ft/ft) that will dictate treatment type.
- .. determine peak flow, **Qpk**, for 10 year 24 hour event.

For R-2, these amounts range from 2 to 4.2 inches. Use values from the state rainfall atlas or similar publication. Equation:

Qpk, cfs = CDA * 1.37 * (Design storm - 1)

E.g. if CDA = 0.9 acre and 10yr 24hr = 3", Qpk = 2.5cfs.

C. For CDA outlet, determine **Qnow** for most erosive soil condition. Value = 0 for active rill erosion. Otherwise prorate vegetation if it is continuing to establish: **Qnow** = **Qvege** * %ground-cover/70

D. For CDA outlet, determine **Qrip**, **Qruff**, **Qsprd**, **Qline**, and **Qvege**. Calculate non-eroding discharge, Q__, for disturbed and expected final conditions. Pick an F_ factor and slope for the most difficult spot(s) to be treated.

Q__ = F__ / Slp(ft/ft) ^ (3/2)

Material (Barfield 162 & 201)	Fvege	
Grass mix, nonerosive soil	0.09	
Grass mix, erosive soil	0.05	
	Fline	
Jute mesh, temporary cover (Bar3.2)	0.013	
Fiber glass, double roving	0.057	
Riprap, 3 inch median (d50)	0.047	
	Fsprd	Frip
Fine sand noncolloidal	0.0011	0.0003
Sandy loam noncolloidal	0.0016	0.0004
Silt loam noncolloidal	0.0022	0.0005
Alluvial silts noncolloidal	0.0022	0.0005
Ordinary firm loam	0.0039	0.0009
Volcanic ash	0.0039	0.0009
Stiff clay very collodial	0.0150	0.0038
Alluvial silts colloidal	0.0150	0.0038
Shales and hardpans	0.0484	0.0121
Fine gravels	0.0039	0.0009
Graded loam to cobbles, noncolloidal	0.0197	0.0049
Graded silts to cobbles, colloidal	0.0231	0.0058
Coarse gravel noncollodial	0.0176	0.0044
Cobbles and shingles	0.0508	0.0127

Example: Silt loam & slope = 1%; **Qsprd** = 0.0022/ 0.01^(3/2) = 2.2 cfs

Worksheet Example: Project design storm 3". Soils easily compacted.

Area 1: CDA = 0.3 acre; alluvial silts; worse slope 5%; compacted with rills; about 10% ground cover. Cause has been eliminated.

Area 2: CDA = 0.7 acre; graded loam to <5" rocks; compacted with rills on 4% slopes. About 30% patchy ground cover. Cause has been eliminated.

Area 3: CDA = 1.7 acre; sandy loam; compacted with rills on 2% slopes. About 20% patchy ground cover. Cause has been eliminated.

Area 4: CDA = 0.2 acre; volcanic ash; compacted, no rills; slopes vary from 2% to 4%. Patchy vegetated cover. Cause has been eliminated.

Worksheet Area ID & Treatment	-CDA- acres	Slope ft/ft	-Qpk- cfs	-Qnow cfs	-Qrip cfs	Qruff Qsprd	Qline cfs jute	Qvege cfs
#1 AlvSilt	0.3	0.05	0.8	rill	0.04	0.2	1.1	4.5
#2 GrdLoam	0.7	0.04	1.9	rill	0.61	2.5	1.6	11.2

E. Use the artificial key to determine treatment:

		Goto
1.	Area has adequate erosion protection; (Qpk <= Qnow)	Exit
1.	If area does not have adequate vegetation; (Qpk => Qnow)	2
2.	If CDA = 0 (i.e. not connected to stream system) low prior	Exit
2.	If CDA > 0 & compacted soils > 4"/hr infiltration rate	3
2.	If CDA > 0 & compacted soils < 4"/hr " "	4
3.	If BlkDn > ____ g/cc (re: plant needs)	4
3.	If BlkDn < ____ g/cc (re: " ") & Qpk < Qruff	Roughen
3.	If BlkDn < ____ g/cc (re: " ") & Qpk > Qruff	7
4.	If Qpk < Qrip	Rip
4.	If Qpk > Qrip	5
5.	If Qpk < Qsprd	Rip & Spread
5.	If Qpk > Qsprd and Qpk < Qvege	6
5.	If Qpk > Qvege	Mech Stablzn
6.	Match Qpk to Qline for different temporary linings	Spread & Line
7.	If Qpk < Qvege, match Qline to Qpk and add lining	Rough & Line
7.	If Qpk > Qvege	Mech Stablzn

How should Area #1 be treated?

How should Area #2 be treated?

>>>> Rstb Road fill & bank stability, sqft 1
>>>> Vbfr Permanent vegetation buffer for sedmnt cntrl, linft 0 0.2

Perspective: Buffers are effective for sediment and pollutants such as nutrients or biocides.

Design Criteria: At the very least use the buffer equations such as Vbfr for sediment related impacts. Anticipate the future condition of the buffer and design based on that.

>>>> Vcvr Vege cover density for on-site erosion cntrl, sqft .1 1
>>>> Vexc Vege protect by livestock exclusion, mi elect= 500, barb= 3000

How to review the photos:
These photographs start with the least expensive sediment control and progress, more or less, to the more difficult or expensive measures. During your review, be aware of how these can fit together in an economical mitigation plan.

- Vegetative buffers
- Drain roads, trails, and compacted sites.
- Harden recreation trails
- Sediment traps, pits
- Sediment traps, channel dugouts
- Sediment traps, bales and fabrics
- Channel stability
- Bridge and culvert stream crossings
- Fords and drive-throughs
- Rip and spread
- Road obliteration
- Road slope stability
- Locations to avoid
- Diversions and channel changes
- Sediment removal

Sheet M1 Vegetative Buffers

Discharging road and trail sediments onto a functioning vegetative buffer is long term and inexpensive, if not free, water quality protection.

M1 UL shows 2 types of buffers. Left side is a swale which is a good buffer; it is not channelized, eroded, or compacted by past uses. The far slope with vegetation litter, and large woody debris (lwd) is an effective buffer also. Both are ideal situations and work well.

M1 UR shows slash from thinning; material laid down more or less on contour can add roughness and barriers to trap sediments. Note the extent of rock and lack of vegetation and litter on the original surface; adding large woody debris such as thinning slash definitely helps the overall sediment control buffer.

M1 LL These sediment flows are caused by storm runoff and snow melt running over the edge of the road and creating gullies in the fill material. The condition is extensive over several miles and has overwhelmed the natural buffer capacity. The log erosion barriers ordinarily work well; however, in this case, they are out matched by the volume of material coming down hill. What is needed is to back haul the mass of sediment already in and on the slope near the stream and to stabilize the remaining sediment on the slope and the road fill. Then, the log erosion barriers might be helpful.

M1 LR shows the result of new road with extensive bank failures that drain into a perennial stream. Remedial action is to add drains along the road so the material flows onto vegetative buffers rather than into the stream. The topography and vegetation makes an excellent buffer to stop further stream damage. The next step is to add sediment channel traps so material already in the system and that caused by further road erosion has a place to drop out. The channel traps will require periodic cleaning.

<u>Sheet M2   Drain Roads, Trails, and Compacted Sites.</u>

Cross drains, be they called water bars, rolling dips, or road rolls, serve the purpose of moving water away from the road to reduce surface erosion and maintenance costs. It is essential to the water quality issue for grade cross drains to be built-in as the roads are constructed. If the cross drains are constructed at 90 degrees, then loaded trucks are not "racked" as they move over it, and there is less argument from those that have to use the road.

M2 UL shows a small dip that takes advantage of a natural buffer. Overall distance between dips is short enough that road erosion is minor and maintenance costs low.

M2 UR shows rolling dips built into a timber harvest unit using standard BMP's as written in late 1970's. The drive through is easy; and water is permanently controlled. Even if the area is open to year around use, rutting is not a likely to cut through and create down slope road erosion.

M2 LL shows a typical water bar. The location is good; makes use of a vegetative buffer before encountering the stream. However, the water bar has been tracked through and surface water drains down the road. This is often a problem with water bars on roads planned for seasonal or temporary use; and thus are not designated for wet weather use. But, unless there is real physical closure, such roads receive year round use. Water bars that are constructed after the sale is closed are "add-on" cross drains constructed of loose material; they are particularly vulnerable to failure during wet season use.

<u>Remedial</u>:

-- A typical solution is to not do anything except hang a "closed" sign on it; and drive around with a book of citations for violations. This might be the only short term solution available, but it is a poor substitute for either a genuine physical closure or construction that makes the resource itself less vulnerable.

-- Might try adding enough rock or spot gravel to prevent track through.

-- The best long term solution is a combination of location and up grading cross drains to rolling dips before or during the next timber sale.

M2 LR shows a location that takes advantage of topography. The road drainage includes a series of rolling dips including this segment with an adverse grade that drains out through a vegetated swale. The swale can handle the road water and sediment without eroding the buffer. If the road were built to gain elevation continuously, a culvert would be needed and require some amount of maintenance to keep the culvert clear and prevent storm flow from continuing down wheel tracks. As it is now, the road grade is gentle enough to maintain stability, now as well as after closure. The resource itself is designed to be less vulnerable and not rely for protection on a gate closure (which have a habit of swinging).

Sheet M4 Sediment Traps - Pits

A hole in the ground is simple, but effective sediment control for projects located on geologies that weather out sands. If holes are installed at the same time as culvert installation, the excavated material becomes part of the road bed itself, or it can be spread along the fill slope and seeded. Note that a pit is a hole -- not a dam -- which means the sediment trap capacity is created before the impact, does not obligate future maintenance, and continues to function until it regains its original contours.

M4 UL At the time of culvert placement, for example, dig a hole about 2 feet deep by maybe 10' square and work the spoil material back into the culvert construction. Note the pipe is not dug down and that it lays on original grade, and the hole is down slope a little ways so there is no interference with culvert maintenance and drainage. Note also that the down slope edge is on contour so storm flow is not concentrated on the buffer.

The value is to trap sediments turned loose during construction phase. Where the hole can be used it is much easier than a "silt fence" or straw bale barrier and has the added advantage that there is nothing to fail. This one was placed in the mid 1960's; up to 30 years of construction sediments followed by day-in day-out sediment control.

M4 UR. Note the sediment flow back in the trees. This pit is an effective sediment trap and, because of the volume, needs to be routinely cleaned out. The excess material is merely shoved out of the way to a site protected from storm runoff. It is effective but somewhat expensive.

M4 LL The reacher pipe was added 30 years ago, just after the original construction. Sediments move to a pit on the far bank and settle out. Reachers work well and may be the best available for retro-fitting pipes like this one. In the early stages of design or during the plans-in-hand inspection, the culvert could have been moved up road about 50' and the natural buffer would have been sufficient to provide the necessary sediment control.

M4 LR A typical day-light ditch located at the shortest distance between the road and the stream. Several sediment control alternatives are easily available to prevent stream damage: 1) if the pipe has to go here, then set the pipe at natural grade (no daylight ditch) and maximize the use of the buffer. Creating this rolling dip with a culvert cross drain has some advantages in preventing storm flow from eroding the road surface. 2) Before construction, move the pipe either up road or down road to take advantage of the longer buffers.

Remedial:

- move the ditch so it flows toward the buffer area downslope; or
- add a pit to the side of the ditch so material has a chance to settle out before the ditch water gets to the stream.

Sheet M5 Sediment Traps - Channel Dugouts

A dugout or hole in the bottom of a stream is simple, but effective sediment control for streams that transport sand. Notice that this is not a dam; which means storage capacity is created without installing structures, and therefore, without obligating management to future maintenance. Once the larger material in the bottom has been removed to construct the dugout, periodic clean out can be done with a suction dredge, backhoe, or dragline.

The dugout needs to be large enough to trap the sand size bedload, have enough capacity for an efficient operation schedule, but not be so large that detritus removal upsets the stream's normal biological energy relationships downstream.

M5 UL. Dragline operations keep the machinery out of the water. But it does not work well if there are buried logs, hard pans that must be penetrated, or coarse rock. The second stage of this operation is to grade off these spoil piles, pull them back from the bank and stabilize the material so erosion is prevented. Key ingredient is location of such sites. Road access for equipment, a safe place to deposit the spoil material, and for future maintenance a place where a suction dredge can discharge with out creating a problems. CWA S404 guides this kind of channel work; depending on the project circumstances, you may qualify for the exemption or need to follow the general permit. In either case, you'll need to determine what is and what is not legally acceptable for the state you are in.

M5 UR. Use a backhoe to construct dugouts in larger materials like these cobbles. This is the only time the backhoe is in the water. Note the bucket "thumb"; it is particularly useful in working streams with large woody debris. If this dugout had been constructed as part of a road crossing, then some of the material could be used in the road crossing to reduce costs for hauling and revegetating the spoil site. If the bottom material is coarse enough to serve as rip-rap or to add protection on eroded curves, the backhoe can be used to precisely place large material and solve two problems at once.

M5 LL. The streams in this area are low gradient; nevertheless, sands are transported during most flows. The dugout capacity is reduced by the advancing wave front formed from bedload material. Sand, therefore, will make up most of the inorganic catch, with silts and clays carried off in suspension. Unless it is planned as a one-shot deal, dugouts require periodic maintenance. With that in mind, select sites that allow assess for equipment and enough area for the spoil. Then design dugout dimensions to trap the sand, but not organic debris, and not so deep that follow-up maintenance, such as with a suction dredge or backhoe is difficult. For wider streams, the dragline works well for clean out.

M5 LR. This is a good site for a channel dugout. There is good access to the site, a place for spoil material away from the forces of floods, and gentle enough topography so the initial effects of construction will not be visible long. If the material is fine grained it can be worked with a dragline; if coarse bedded, with a backhoe. The spoil needs to be moved away so it does not interfere with the flood plain functions or fill in wetlands.

Sheet M6 Sediment Traps - Bales and Fabrics

Straw bale and silt fence sediment traps can be installed quickly to respond to emergency situations or be used in areas where machine constructed sediment traps are not needed or more expensive. Silt fence fabric may also be more effective for fine grain sediments than a comparable sediment trap dugout. A combination of construction short term control and longer term erosion and sediment control using vegetative buffers and holes is cost effective.

M6 UL A series of checks may be needed to provide ditch grade control. This one is made from staked down straw; when the trap is full, it has to be cleaned out it order to remain effective. This is very short term and high maintenance item; the application of these ditch structures fits between the dates of expected road maintenance to avoid interference with normal operations.

M6 UC Erosion blankets provide temporary protection during revegetation. The design is based on preventing erosion so vegetation can become established and considers expected peak flow, soil characteristics, and slope. Coconut fiber mat, followed by grass seeding will produce a stable ditch, whereas just reseeding would probable wash away before the ditch could handle the flow.

M6 UR The use of bales or fabrics implies short term control objectives as might be expected for seasonal construction. Each filter trap has a relatively small capacity; its construction and location is best suited for conditions where hand labor is efficient or the final project layout can not include sediment pits. Locate filter traps on the slope such that the expected sediment levels will not wash around the ends or block flows from the culvert. This trap is effective, but requires maintenance; you just can't install and forget.

M6 LL Select sites that use as much of the vegetative buffer as you can. Make sure the ends are high enough to prevent flow around the edges. On newly disturbed areas, use bale/fabric traps to help handle the high sediment flush so the vegetative buffer is not loaded up. Then after the construction phase, rely on the buffer to maintain stream health from the day-in day-out sediment loads. For this particular site, the trap location is not particularly good because it minimizes the buffer distance and room available for further work. The double defense filter trap is a good use of the small space, but has a high maintenance requirement. The straw bales will eventually melt, but the silt fence will require one final visit to pick up the junk.

M6 LR Adding energy dissipators will spread the flow out and increase the life and usefulness of the sediment traps. This culvert discharges onto rock and into straw bales. The small amount of sediment buffer means erosion control efforts have to very effective or the agency has to commit to sediment control long after the erosion control and revegetation work has been completed. Or stream damage will continue.

Sheet M7 Channel Stability

We want channels to remain stable; when they are not, the change in equilibrium creates massive amounts of sedimentation and high restoration costs. The purpose of channel protection is to modify one or more streamflow factors so channel stability is maintained -- or in cases of past damage, regained. Design manuals are readily available and should be consulted before project action creates stability problems rather than after the damage has started.

M7 UL Road picks up 2 minor draws and adds to an existing downslope gully system. The draw contains several such rock checks, of which this is the first. Design: pay attention to erodible soils and try not to collect more storm runoff than the channel can handle. Remedial: nothing further; this was expensive enough.

M7 UR State highway construction with gabion baskets to protect the inlets and outlets and to support the fill material above it. Note the loose rock used as a blanket to stabilize the road ditches. Remedial: none.

M7 LL A minor mistake in the wrong place, but because of the sensitive nature of this water supply, erosion matting was installed immediately. Any delay would increase the risk of stream sedimentation that would have to be removed later with a suction dredge. Matting extends from the creek to the first rolling dip; rolling dips drain the road section above it on to suitable vegetative buffers. This matting is effective, but expensive.

Design: if a channel or erodible surface can be stabilized with vegetation, but needs some help with revegetation, then matting such as this plays a key role. Design criteria are available.

M7 LR Area of disturbance was too much for a lone set of straw bales and some straw mulch. But it tried. Design: if straw bales are to be used, then specify both placement and maintenance so they can be effective. However, just a general contract spec for straw bales will often result in failure during the next storm. If there is room, consider replacing the bales with holes or pits.

Remedial:

-- this project could have started by digging a hole or trench in the channel bottom (channel trap) as a preventative measure. The excess material could then be used for a berm or to fill a wash out. That trap still needs to be built, then finish putting in enough bales to take care of the next storm.

-- If there is room, consider replacing the bales with holes or pits.

Sheet M8 Bridge and culvert stream crossings

Ordinarily road crossings will be planned and executed under CWA S404 nationwide permits issued by the COE. The permits specify management practices as well as engineering criteria such as the capacity to pass expected flood flows.

M8 UL The culvert is well sized, the inlet and outlet are protected, and there is minimum disturbance because the road crosses at a right angle. The downstream bank is some what exposed to the flows from the culvert and could be trimmed up a bit; however, the problem is minor.

M8 UR The culvert capacity is greatly reduced by the deposition; it should have been cleaned out just after the initial event, but certainly before the next spring runoff. Then take a look at sediment source areas and begin the restoration planning. In particular, if the upstream geology is unstable, put in some upstream channel dugouts to help protect the culvert installation.

If road operations blade excess material into stream channels; then stop. This creates S404 liability. If you have to design "minimum standard" roads that rely on bank collapse and "maintenance" to eventually create a stable road, then find a place for excess materials without creating stream impacts.

Remedial:
- -- locate a disposal site that can be protected, then clean out the culvert and both sides, and back haul to the disposal site. It is not acceptable to flush this stuff down stream.
- -- put in several channel dugout traps downstream.

M8 LL The culvert construction and its capacity to pass expected high flows does not meet S404 Nationwide Permit requirements. Nor does it conform to the engineering standards used by the local agency that built it. It just sort of happened; for starters, the culvert was too small and far too short to meet criteria, but used anyway because it "was available". The result is a road bed, barely wide enough for a running track, with continual stability problems, and no inlet or outlet protection. The fill material is soft, loose, and easily washed out. Some of the material from previous washouts is visible.

Remedial:
- -- 1) excavate the material from past blowouts before it gets pushed further downstream and becomes more expensive to clean out;
- -- 2) put in a set of channel traps to help control sediments;
- -- 3) either rebuild the crossing to NWP requirements or take it out; and
- -- 4) make an impact on persons' responsible, so it doesn't happen again.

M8 LR Great bridge. With a little care, it should go for another 50 years. But it needs a little repair and a clear channel if it is to survive the next big flood. Design: something in terms of location and workmanship to emulate. Remedial: remove the rock and fix the bridge. Find out if there is a road crossing inspection within recent years and see what else needs to be done.

Sheet M9 Fords and Drive-Throughs

For many stream crossings, fords and drive-throughs make both environmental and economic sense. They do have to be stable under conditions of high flow and expected vehicle use. Ordinarily, the necessary particle size distribution can be obtained with minor treatment of local gravel sources.

M9 UL Temporary road pushed into the channel for a crossing. Subsequent storm runoff added both large and small erosional debris; the road was then abandoned. Flows are forced into the other bank creating accelerated bank erosion and down stream sedimentation. Proper design would have included capacity for expected flood flows, correct placement, and stable materials.

Remedial:

-- obliterate the road, take the material back out of the channel and return the stream to its original course and elevation.

M9 UR The ford (upper left) is on stable gravel and small cobble material. The sedimentation is mainly from erosion on the approach to the ford.

Remedial:

-- move downstream and put in a channel trap; drain as much of the road onto buffers to minimize the amount of approach that has to be hardened. Then rock the approaches and the ford with 3" minus river run gravel.

M9 LL Material found near a stable ford that is less than 4" and with minimum sand or other fines. Material appears to be about the right size for both stability and hardening the site. Remedial: no action required.

M9 LR Old wagon road through sandy soils and geology. The location is not bad and the bottom is gravel and cobble and fairly stable.

Remedial:

-- drain as much of the road onto buffers as possible, then harden the approaches with 3" minus river run gravels.

-- In the ford, add enough large rock to prevent the upstream hole from developing during high flows; if local rock is too small to be stable, then try adding a steel "I" beam, geotextile webs, or a concrete pad downstream to support the ford materials. Do not use gabion baskets; broken or exposed wire creates both tire and safety hazards.

Sheet M10 Rip and Spread

The objective in closing these steep roads is to use heavy equipment to prepare a final shape and suitable seed bed that does not have any residual machine tracks to concentrate storm flow. Typically, that will mean ripping in one direction and respreading the material turned by ripping into a flat contour during the "back out". However, if the road grade is such that there is no concern about channelized erosion, then a one-pass rip would be enough.

M10 UL The last time the road was used was over 10 years ago. Erosion will continue until we use some mechanical treatment to change storm flow patterns and provide a seed bed.

Remedial:

- -- Use rip and spread techniques. Rip deep enough to break up compaction and then blade fine material back onto the surface for a reasonable seed bed. This pass for seed bed needs to create a flat contour so there is no longer a place for flow to concentrate. If the channel is stable and revegetated, leave it alone and work on the areas that need help.
- -- Pull material that is forcing or restricting the flow back out of the way. Plant trees so there is no doubt that the drainage is closed to all future transportation use -- including skidding.
- -- Be aware that past road or trail construction may have opened cattle trails that are now in common usage. If this is the case, harden the trail and forget the restoration.

M10 UR Material shoved into a pile is not a closure; the return of this site to productivity requires some mechanical treatment to insure infiltration and a good seed bed. The large berm can be respread back uphill during the rip operation. The ditch (left side of photo) is currently stable and the buffer it drains onto will be adequate once the accelerated erosion has stopped. Step 1 is to rip areas that are too compacted for seed bed and areas that need to be reshaped to obtain a flat contour and a more or less constant grade. If there has to be steeper sections then locate these to coincide with coarse rock fragments or erosion resistant materials; in all cases, eliminate cascades or other gradient surges that will not be stable. Step 2 is to spread material, including that from the berm back up the draw. Step 3 is to protect from livestock use. Step 4 is to seed and plant.

M10 LL No further equipment use; area has recovered adequate vegetation and debris down draw so the effects from high intensity storms should be minimal. If the area is expected to have concentrated livestock use, then protect any areas with new seeding and planting.

M10 LR Area will not stabilize without some form of mechanical treatment. Logging roads have rearranged natural drainage ways and forced concentration in tracks that are now actively eroding with headcuts and sheet wash. Rip areas that are compacted, redistribute material to rebuild and flatten the original drainage pattern; and respread material as needed for a good seed bed. Seed and plant; permanently close the road and relocate trails for the next harvest.

Sheet M11 Road Obliteration

For a variety of reasons, some past road and trail locations are now slated to be obliterated. The current effort to relocate roads to better locations and to close roads will continue as one means of improving stream health conditions. During environmental analysis for projects, CWA S404 directs alternatives to minimize sediment discharges into "waters of the U.S."; and to avoid discharges into T&E critical habitat, migratory waterfowl habitat, spawning areas, special aquatic sites, public water supplies, and National Wild and Scenic Rivers.

M11 UL This compacted road was ripped to a 16" depth with one foot spaced teeth. This is not inexpensive, so give some thought to the long term result you want to accomplish. If the area is to be reforested and removed from the transportation system (roads and trails), and the bulk density is the limiting factor as far as tree growth is concerned, then ripping, followed by spreading, followed be fertilizing, followed by planting is a worthwhile step. If the road/trail is poorly located, ripping, followed by recontouring, followed by planting for erosion control is a worthwhile step. If the road/trail is well located and part of the long term transportation plan, then perhaps to scarify and seed is a better choice than ripping.

M11 UR This type of slash treatment follows ripping with the intent of providing a mulch protection. The standard is to scatter 10-15 tons per acre of large woody debris (>3") and additional material (<3") to achieve a 30% ground cover of woody material. Where slash is limited, weed free straw may used for up to 10% of the coverage. The loading shown here is about 50 tons per acre.

M11 LL Unstable cutslopes along roads tend to recede upslope and produce top-of-bank headcuts. These will continue to slough and recede until the bank and vegetation achieve stability. If basic bank and vegetation have resulted in stability, or will do so with project action, removing the top-of-bank headcut helps remove a source of sediment. However, unless the final design is stable or can be stabilized by vegetation within the construction time frame, the effort may have little long term value.

M11 LR Major road obliteration at this drainage included removing 14,000 cubic yards of fill material. Road bed was ripped, respread, mulched with material including large woody debris, and planted. Raw stream banks were stabilized with large rock, brush blankets, and plantings.

Sheet M12 Road Slope Stability

Roads located on unstable geology create substantial and long term sedimentation problems. The first step is to establish effective erosion and sediment control measures on existing roads and not make the same mistakes again. Road standard, location, maintenance practices, and past indifference to effects, coupled with geologic instability and harsh sites for revegetation, combine to make stream health recovery difficult, vastly expensive, and decades long.

M12 UL The massive instability problem here is somewhat improved with this engineered buttress; the "H" steel posts are set in concrete and designed to support this slope. The lower metal bin wall supports the upper road surface; the lower road will be obliterated. From a design standpoint, there are two questions: First, what other alternatives are possible that would also reduce short and long term impacts? Like allowing narrower road sections. Second, given this hillside, will a native vegetation root system ever be deep enough to stabilize this hillslope <u>without</u> the steel buttress? If no, then what measures can be used to reduce reliance on agency protocols and long term maintenance.

Determine the expected drainage for the slope and install sufficient sediment basins to keep the debris out of the stream system. Given the magnitude of the problem, design each piece of the control strategy for long term effectiveness and low maintenance costs. The process is expensive, but necessary.

M12 UR Geologic area with difficult surface revegetation problems. This slope is internally stable, but has extensive surface erosion. Treatment with slabs and logs takes advantage of what vegetation is already in place and provides enough support to establish plantings to fill in the gaps. The slope steepness and character makes such revegetation difficult and quite vulnerable to damage. In order to ensure success, this revegetation effort must also be combined with proper road maintenance practices. In particular, practices such as "pulling the ditch" need to be done without undercutting the bank.

M12 LL This is the same area as M10 UL. Cut slope has been backsloped to a little better angle of repose, then planted. This area is located in winter range and revegetation efforts tended to get hammered by wildlife. The 9′ high fence was added to exclude wildlife and a drip irrigation system installed to help reestablish newly planted trees and shrubs. An example of a rock buttress is on the bottom right of the photograph.

M12 LR An area similar to M10 UR with difficult surface revegetation problems. Rock outcrops suggest the cut slope is internally stable but with extensive surface erosion. For surfaces that are very irregular, the grid system spans the gaps and provide a structure from which to hang or hold loose woody debris needed for site protection. Shrubs and trees are planted in the grid as necessary to develop the slope coverage needed. The grid is not intended to function as a buttress, however, so the slope has to be stable. Also, since the "feet" are on the road surface, take care that the placement is away from the areas that will need routine road or ditch maintenance.

Sheet M13 Locations to Avoid

The value of transportation planning is to define a long term system needed to accomplish the goals. Sometimes parts of the system do not serve long term needs, but -- from an engineering standpoint -- are stable and not a problem. However, when road locations, either permanent or temporary, encounter unstable geology or flood prone areas then the long term needs should be able to justify the expense associated with proper erosion control and stability. The point is not to enter such areas willy nilly and create long term liability, maintenance problems, and stream health problems.

M13 UL Unstable geology in land slide topography. Road construction is particularly vulnerable because deep cuts into subsoil drainage patterns and the disruption of natural patterns. Not all areas are this bad; i.e. unstable even under natural conditions, but often similar conditions at smaller scale can be seen and avoided. This highway is at least 50 years old and the cut banks are still not revegetated and constant repair is needed to keep the road open.

One design consideration is to stay off and find another way even if it costs more. In terms of forestry, an alternative to timber harvest is to leave the trees in place to provide slope stability.

M13 UR Unstable slope conditions derived from loose and fine grained volcanic soils. Any activity will require major investment in mechanical slope stability. The channel demonstrates a natural condition; there is no activity in the watershed, so all of this is natural response. Design: unless money is no object, do not construct roads or any corridor that concentrates water. Remedial: this watershed is not impacted.

M13 LL Unstable soils and geology aggravated by extensive slope springs and wet conditions. Road construction was difficult because of the water; cutting into the sidehill released stored water which now flow during wet weather. Routine maintenance is not even attempted. The "temporary" road system put in during one logging season will either take vast amounts of resources to make right -- or which is more likely, will never be repaired.

Design: avoid areas like this with cuts and fills. If the area is to be logged, consider stump roads, long skid trails, and winter logging.

Remedial:

-- Given the complexity of the final logging road layout, start at the top and piece together the existing channel patterns, then work toward reestablishing natural drainage, at least to the extend that erosion is not further aggravated.

-- Recontour roads with unstable fills. Pull unstable fill material back out of the creek and redeposit the material along the inside edge of the cut slope. Reshape the profile to blend with the natural contours and replant with deep rooted species for mechanical support.

M13 LR unstable geology, poor vegetation cover and growth, and a fast watershed response to rain storms and spring snow melts. Design: truck trails in and along the bottom might work if temporary access was needed. The side slopes aren't too bad in many places; however, the road layouts so far tested always encountered slopes that could not be stabilized within the economics of the project (oil exploration).

Remedial:

-- nó road was constructed; nothing to fix. If there was a road, how would it be done? Start at the top and re-establish natural drainage, recontour and/or buttress failure sites, and drain away from the inside edge. This would still only take care of a minor part; the rest would never restabilize.

Sheet M14 Diversions and Channel Changes

The typical solution to a host of land use activities is to move the stream. This introduces water flow dynamics that involve major changes in equilibrium, the power of the stream to do work, and sedimentation properties. There is nothing simple or easy about designing a channel change and too often, we just cut a new path and watch things come apart. Be aware, that a channel change requires a COE S404 permit and evaluation using 40 CFR 230.

M14 UL Major channel diversion about 20 years ago was designed and fixed as a "stream improvement". The improvement lasted a year before a typical high flow rearranged the structural improvements, tore out the banks and generally created the typical gut channel we are used to seeing. The original channel went through several rock outcrops and a boulder channel. The new location for the channel change had to go through glacial material -- which is not known for it's stability. Riprap material of a size large enough to handle the flow conditions now has to be imported to the site. The massive effort to stabilize the channel with riprap and grade control structures continues to date. Even ignoring the sedimentation damage to downstream facilities, one wonders if all this was really that much cheaper than putting in the 2 bridges.

Design: the first single most important rule is "no". You can design and put in road crossing and have an idea of what is going to happen. When channel changes are made they are often done for short term economics, do not include the real costs of doing the job right or damaging down stream users, and are often started with minimum information.

Remedial:

-- there are no simple solutions to this. With the original channel in a stable location and next to a popular campground, you might check into the possibility of putting the creek back where it was; and use the justification that recreation and fishing near the campground would be a benefit that is not served by the current location. For the current location, there is not much we can do, other than to continue installing riprap for bank stabilization.

M14 UR Recent diversion completed in 1988. Looks pretty good, doesn't it? Considering that the original channel was 22' wide and this one is 14'. The flow shown here is slightly more than 1/2 of what we expect to see as a 2 year flood event. What will happen when there really is a flood flow?

This is the second set of rocks placed to "benefit" fisheries. The first set was about twice the size, blocked enough of the channel to cause severe bank erosion, and stood far enough above the flow to create gravel bars downstream of the rock. These were removed, new riprap added, and lower profile rocks added -- to what you now see.

One could conclude that as late as 1987 we still didn't have any idea of what it takes to make a stable functioning diversion. And when this one fails, the contractor will be gone.

Design: count all (including litigation) costs involved for a stable diversion and the passage of high flows; in other words the diversion should be designed to function as well as the original channel. Or make a policy decision to keep flows in natural channels; we do not know how to do it well enough to compensate for the change in conditions and long term results. It will likely be a higher first cost, but will not be a lingering nightmare and eye sore.

Remedial:

-- there is very little one can do with a poor design that badly underestimates the flows likely to be encountered, even in the short term. The only thing that might have value in protecting down stream values is a series of channel traps to catch material when it does blow out.

M14 LL Diversion around a mine site; long past. Channel is stable and controlled mechanically by a culvert and a concrete sill at the road; then it plunges. Large amounts of tailings are exposed and contribute to down stream toxic problems. Diversion is helpful since it avoids several areas of highly contaminated material.

Remedial:

-- the solution is difficult and expensive. Alternative might be to collect the good water and pipe it through the contaminated area and release it. Or to collect the acid mine drainage and pipe it to a treatment plant. Since the channel itself is stable; the next step is to stabilize the tailings which will also be difficult.

M14 LR Diversion around a campground with no successful attempt to stabilize either grade or bank material. There is no easy or cheap design for a stream of this size. The design needs to mimic natural processes for the flow energy and sediment regimes for a long term solution. Medium range solutions include piping or concrete flumes.

Remedial:

-- can't cure this without a good design; however, we can look for safety hazards, and construct and maintain channel dugout traps downstream.

Sheet M15 Sediment Removal

The enforcement authorities under S404 allows the COE or EPA to select methods of stream health recovery including measures like sediment removal. Recovery can be accelerated by a judicious combination of natural processes and physical treatment. For example, an in-channel dugout that is periodically dredged makes use of natural sediment transport to help reduce the overall project costs.

M15 Upper row. Failure to administer a road construction project and enforce erosion and sediment requirements came home to roost during a high intensity storm. About 1000 cubic yards was flushed into the stream. The purpose of the suction dredge was to take it back out. The equipment was an 8" suction dredge powered by a 1600 cc VW air cooled engine -- and hand shovels.

Make sure the contract carries the necessary specifications; then recognize the high risk situations and administer the contract. Anticipate problems, add storm runoff controls like sediment traps on the slope and in the channel.

Remedial:

-- suction dredge costs were $15,000 for 1000 cubic yards or about $.12 per square foot. Adding channel dugouts help concentrate sediment and makes it less expensive to remove later on after it accumulates.

M15 LL Heavy and long term continuing sedimentation from extensively roaded timber sales. As a design feature, timber sale road layout is the single most critical step. And it needs to be done based on long term resource and development needs and NOT on where this years timber cut is going to be. This is true for both the transportation net as well as temporary use roads.

Remedial:

-- Sand and gravels are locked up in these small patches. Restoration is going to take a while, so stick around. The first step is to install several easy-access channel dugout traps. Then start at the top of the divide and work downslope, using the most economical ways to disconnect sediment sources from the stream system or stabilizing erosion that can not be disconnected. These 5 stages are suggested:

1) Where there is good vegetative buffer, drain disturbed areas to it.
2) Treat connected disturbed areas that only need minor mechanical and vegetative control such as sediment pits or reseeding.
3) Treat disconnected disturbed areas that only need minor mechanical and vegetative control such as sediment pits or reseeding.
4) Treat disturbed areas that need major structural or mechanical investment, such as recontouring or biotechnical slope stabilization.
5) Clean out sediments traps when they reach about 2/3 full.

M15 LR Sediments concentrated in ponds makes it a little easier to clean it out. Design: buffer interception, sediment traps, disconnect sediment source areas. Remedial: something like a backhoe and suction dredge would work. Spread the spoil in a nearby area that can be easily revegetated. Costs expected would be $10-15 per cubic yard. Add channel traps and perform periodic maintenance to avoid more difficult and expensive remedies.

>>>> **Monitoring** - review the need for extra monitoring or intensive field surveys. Direct monitoring efforts to results that are of evidentiary quality & can be used to assess - or restore - CWA Robust stream health.

Back to the beginning. The existing need for top quality monitoring is further accentuated by the latest changes to the Clean Water Act. In particular, Sec 319 requires the evaluation of non-point source pollution control activities in the context of State run programs and existing case law is strong enough to require restoration. In terms of monitoring, these are still key objectives:

- Stay off the State's impaired watershed list.
- Fix watersheds that are currently on the list.
- Fix unlisted watersheds that fail to meet Clean Water Act goals.
- Make monitoring efforts good enough for judicial use under Sec 505.
- Report results in terms of Stream Health.
- Commit people to stay on top of high risk activities.
- Concentrate on eliminating personal levels of liability.

Be aware that good monitoring plans are needed for budgeting and project control; that broad generic statements are useless when the issues are factual; and that the burden of demonstrating compliance is on the agency.

If you have to develop a monitoring plan, at least start with the following questions as a checklist to help focus on the data and analysis needed to meet statistical, mathematical, and procedural validity:

- Have data collection methods been standardized and applied consistently?
- Have analytical methods been standardized and applied consistently?
- What type of data and accuracy is required?
- What time and space is represented?
- What frequency and distribution is represented?
- What is the physical, chemical, or electrical basis of the equipment?
- Does equipment measure what is required?
- Does it have the required accuracy under field conditions?
- How many units of equipment are required?
- Are maintenance and calibration provided for?
- How and when will data be collected?
- How will data be recorded and stored?
- What is the introduced error?
- Is the analysis statistically, mathematically, and procedurally valid?
- Is interpretation logically correct and appropriate to the objective?
- Are the people involved with equipment and collection competent?
- Are the people involved with analysis and interpretation competent?

>>>> Specify where to sample, who is to do it, which methods, parameters to measure, and frequency. Location is critical; look for sites that are 'weak link' sensitive to early stress or that are expensive to fix:

- Bank Comptncy: raw>grs>brs=trs; s>f>>g>>c>b>r; M >>L=J >G >T >R include ad-water, de-water, spill sites, peak & duration changes.
- 1/8 mi (660') downstream of road crossing: culverts > bridges.
- roads that concentrate runoff: design >> temporary > primitive.

The focus is that "Maintenance of ecological integrity requires that any ... physical, chemical or biological change ... be of a temporary nature, such that by natural processes, within a few hours, days, or weeks, the aquatic ecosystem will return to a state functionally identical to the original." Then use the following checklist for defining the when, where, how, what, who, and why:

- Concentration or dispersal of pollutants thru physical processes.
- Concentration or dispersal of pollutants thru chemical & processes.
- Concentration or dispersal of pollutants thru biological systems.
- Effects on key species.
- Effects on natural temperature patterns.
- Effects on dissolved oxygen conditions (food, propagation, cover).
- Effects on natural stream reaches, flows, and circulation patterns.
- Effects of road construction and maintenance on stream systems.
- Effects on aquatic ecosystem stability & diversity.
- Effects on aquatic ecosystem productivity.
- Rates of inorganic sediment accumulation.
- Rates of eutrophication and organic accumulation rates.
- Rates of stream health restoration and recovery.

Monitoring doesn't <u>have</u> to be complicated; think through how the data is to be used and avoid making it more complex than necessary. Monitoring at weak-links in time, space, and administration (or expensive-to-fix areas) is cost effective because it focuses attention on when an impact is expected, where it is likely to show up first, what administration is needed, and who carries the big stick.

Plates to be used with T-Walk Exercises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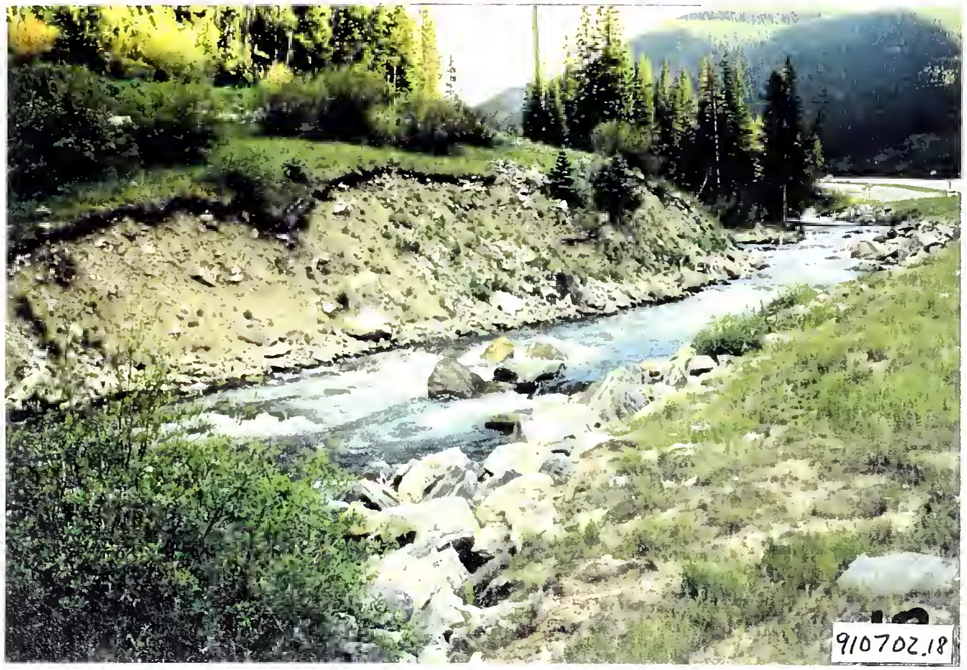
T-Walk B2

T-Walk B3



T-Walk B4

T-Walk B5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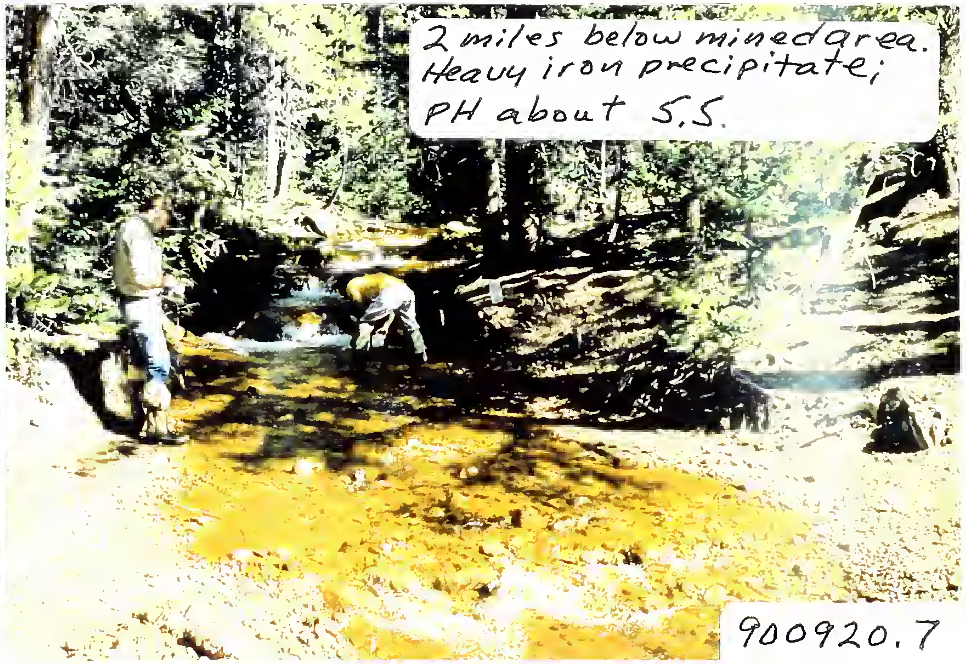
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PH about 5.5.
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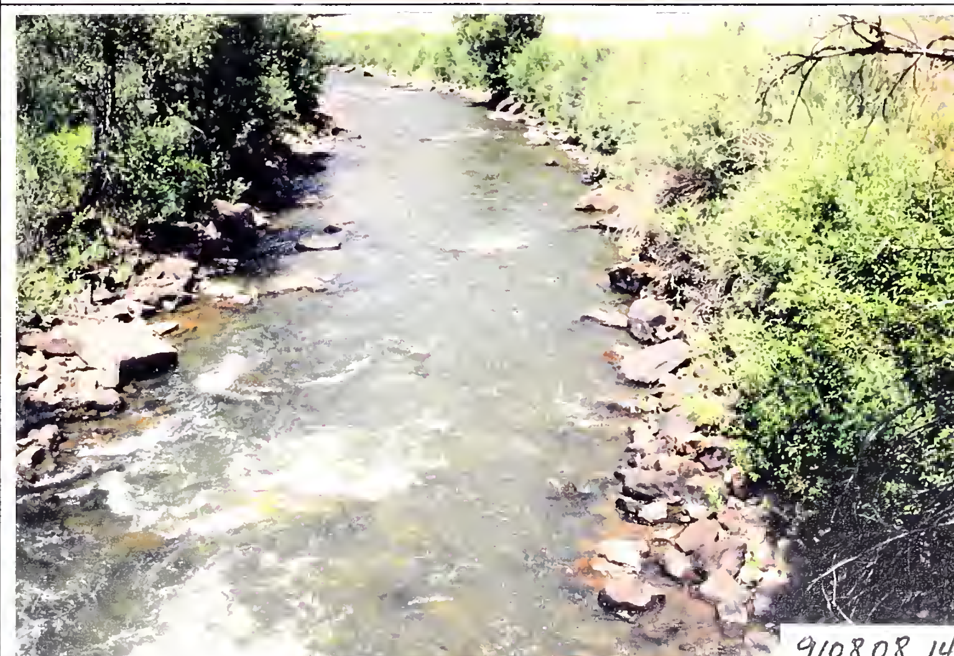

T-Walk D2

T-Walk

T-Walk D 4


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T-Walk D5

T-Walk D6


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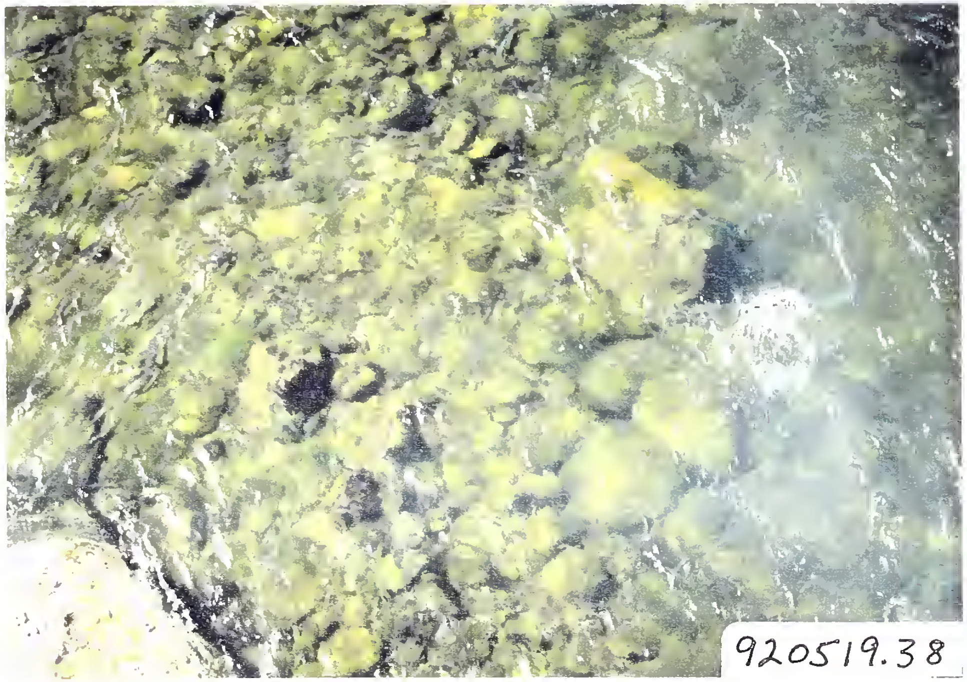
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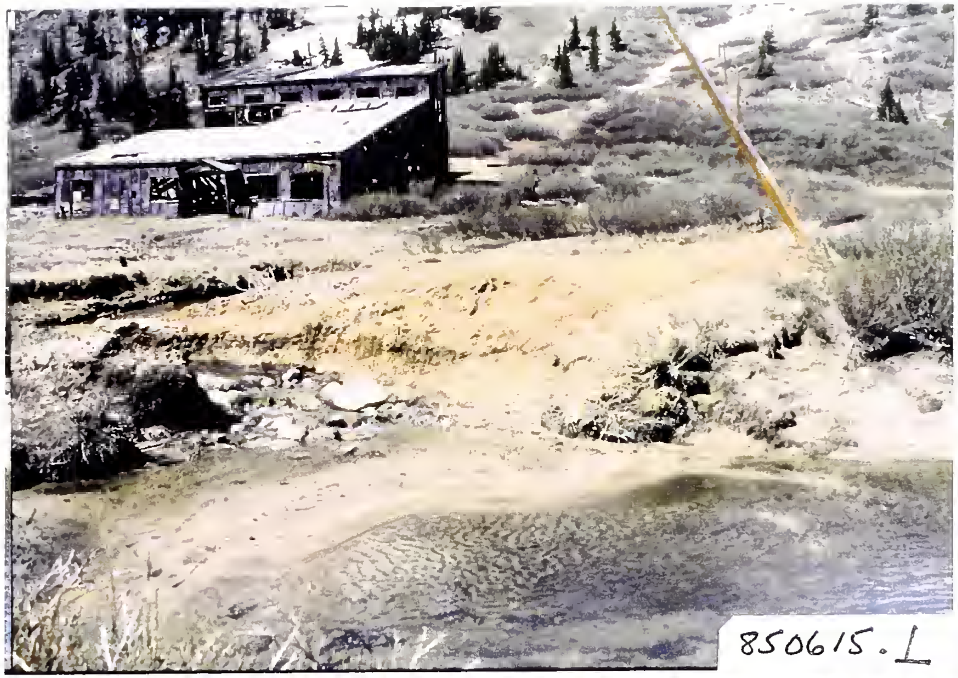

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T-Walk D 8

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T-Walk L1

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414

441

486

T-Walk L2

489

498

502

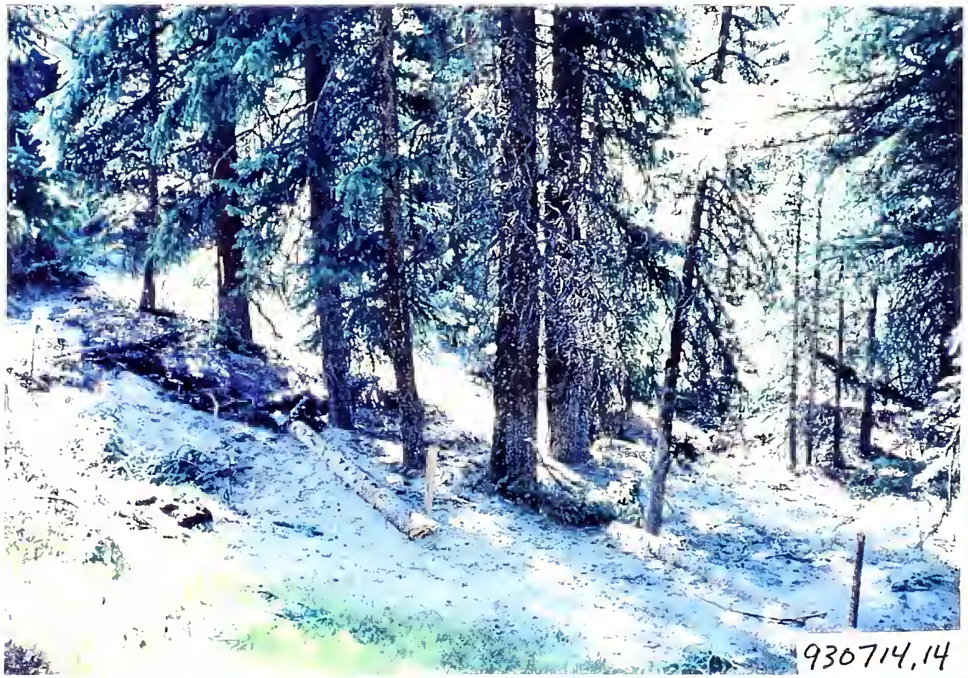
488

497

501

T-Walk 43

T-Walk L4



T-Walk M1

920501.13

910925.12

920420.56

910525.27

T-Walk M2

NO

m- 3

T-Walk M4

7505 MI. 10

7505 MI. 5

7505 MI. 8

7505 MI. 9

T-Walk M5


920925
D.Gordon


920925
D.Gordon

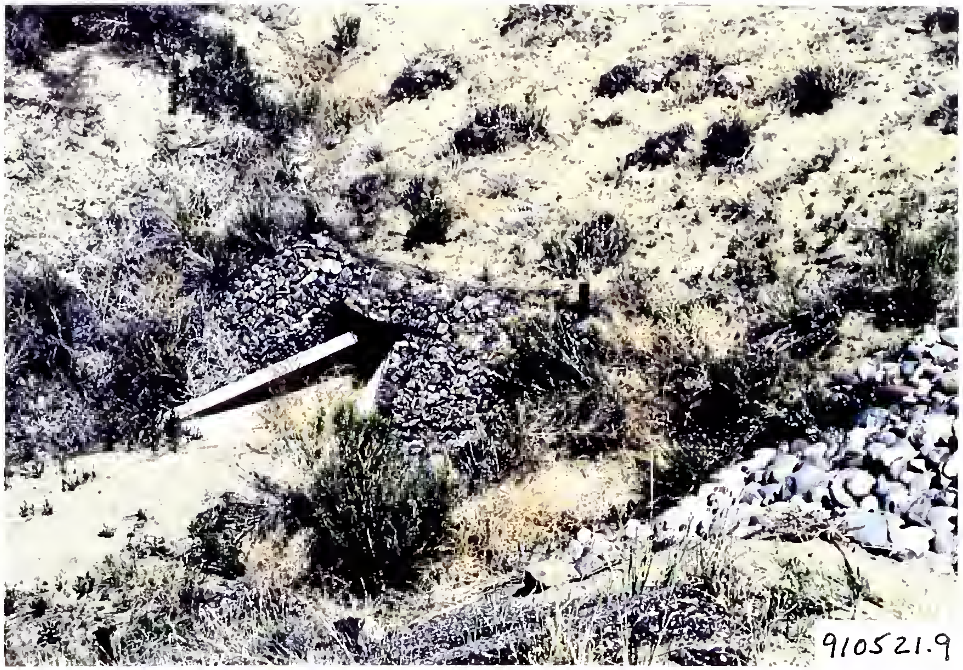

920925
D.Gordon


9310
D.Gordon


9310.
D.Gordon

T-Walk M6


920929.29


910521.9


910912.15


910816.33

T-Walk M7

T-Walk M8


910905.19


920501.47


920501.58


930602.25

T-Walk M9


930522.5


930522.2


930422.15


930521.24

T-Walk M10


93223
D.Gordon


93223
D.Gordon


310D
93223
D.Gordon


93227
D.Gordon

T-Walk M11

930820
D.Gordon

931013
D.Gordon

931008
D.Gordon

9210
D.Gordon

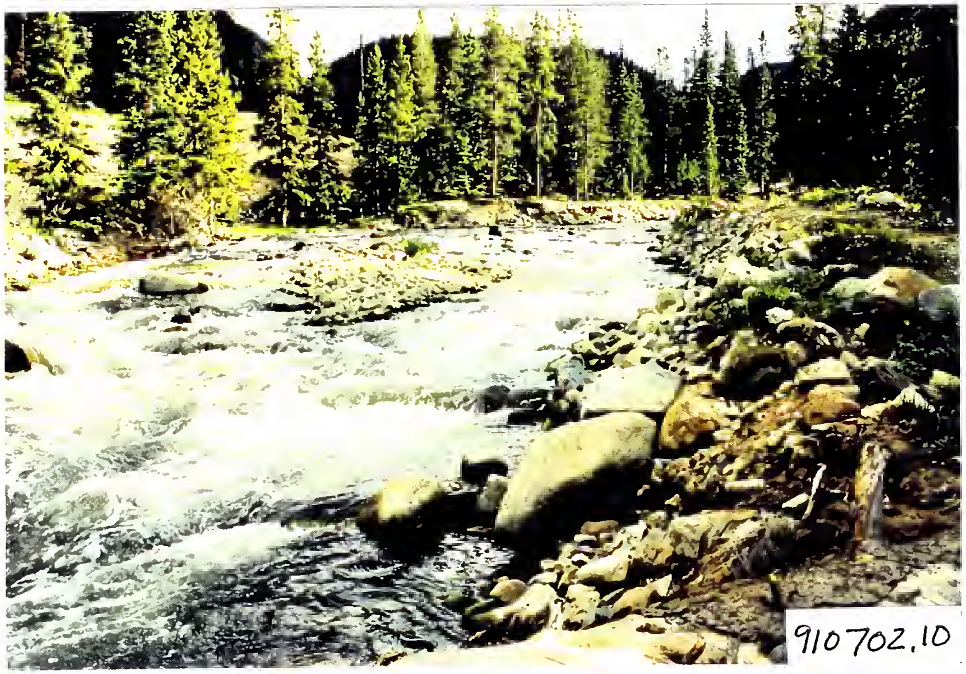
T-Walk M12


920720.?


910515.23


910525.?


911002.14

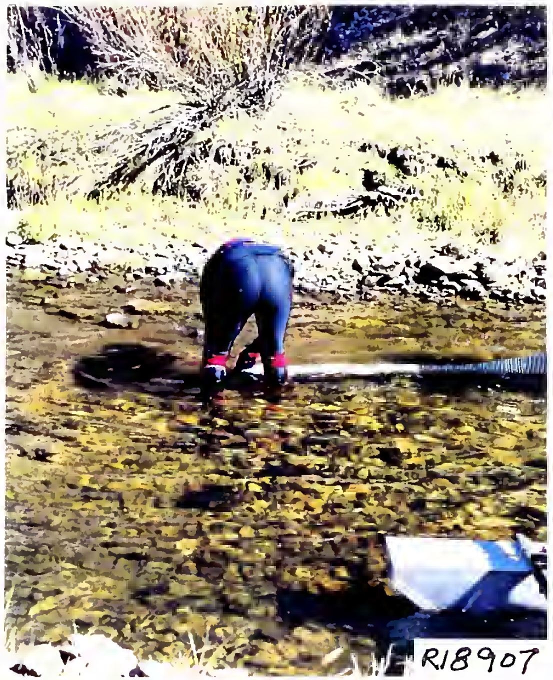

910702.10


930603.25


930602.4


930422.1

T-Walk M14


R18907


R18907


R18907


910627.14


930923.17

T-Walk M15

Flags at Bankfull.
Top of peren. gr. roots

Bankfull flow. Note
Submerged 'Grassline.'

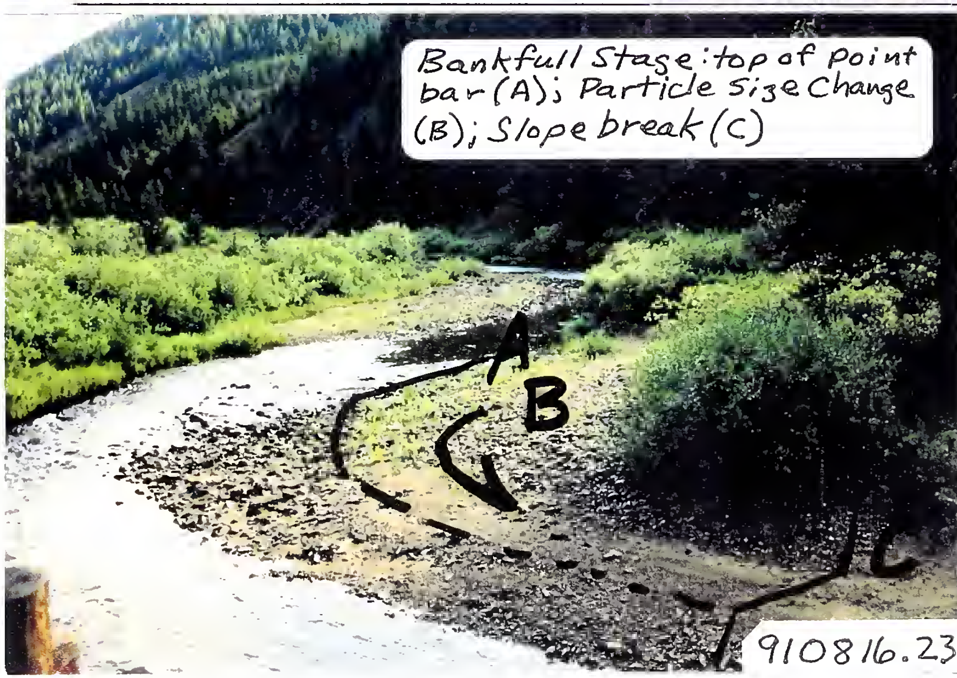
Bankfull at Survey Rod.
Shows slope break and
top of brush root crown.

3F. Bankfull at Rod. Shows
slope break, 'grass' line, &
top of brush root crown.

Bankfull at top of brush root crown.

Bankfull stains (A). Not greater than rock moss (B)


Bankfull Stage at Bench. Foot is on bench flat; 'Grass' line + slope break.



Bankfull Stage: top of point bar (A); Particle Size Change (B); Slope break (C)

Bankfull Stage: Top of brush root crown. Note midchannel bars + bk. erosion

T-Walk R1

T-Walk R2

920420.57

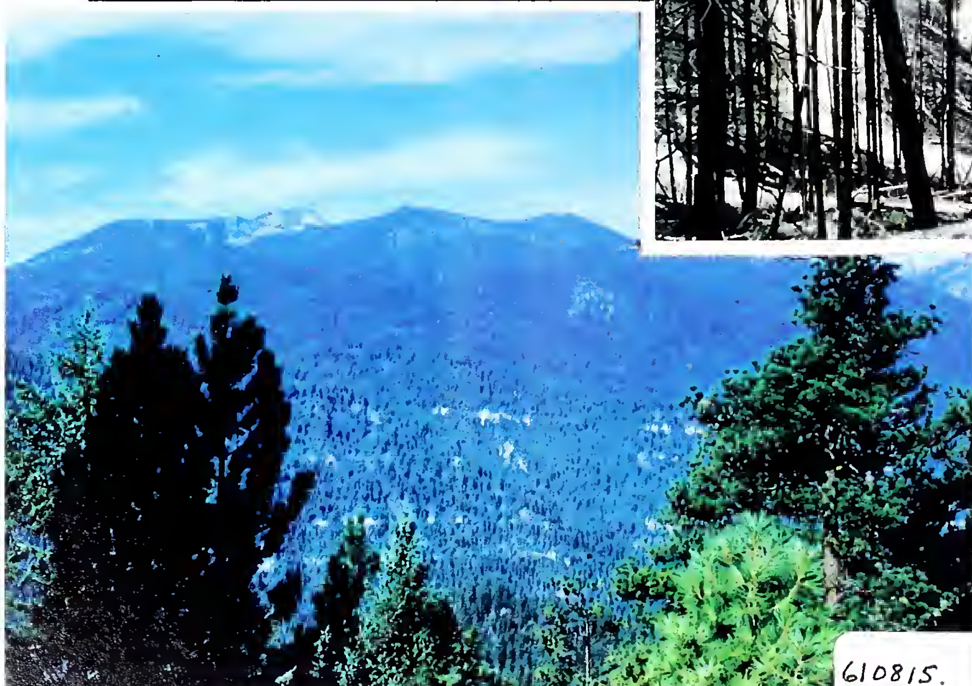
920420.29

920420.31

920420.39

T-Walk R3

T-Walk R4



T-Walk R5

TSR 1

T-Walk T1

TSR 2

910905.9

910816.35

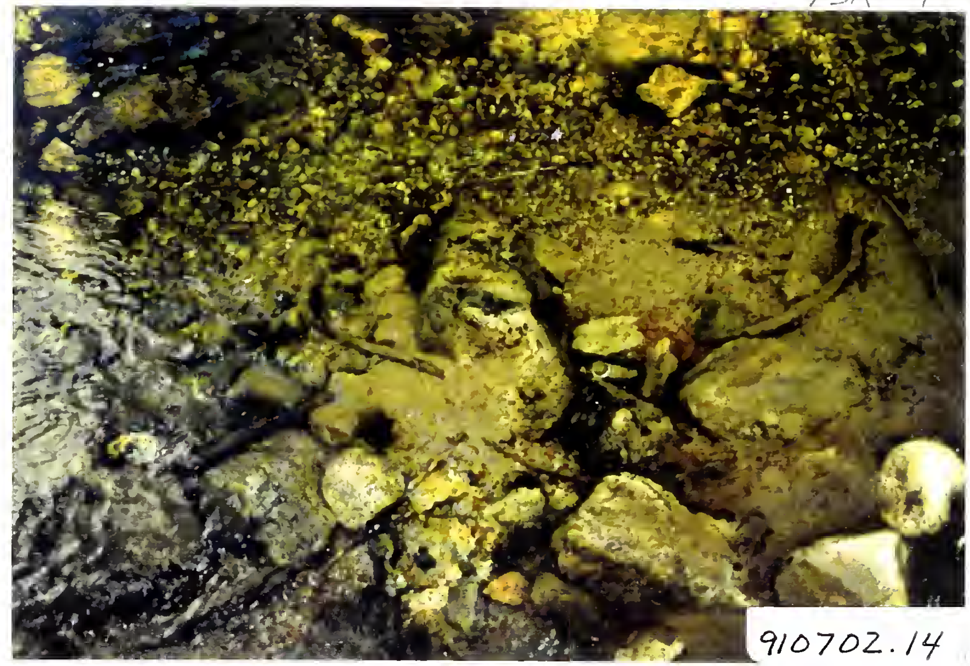
910808.3

T-Walk T2

TSR 3

T-Walk T3

TSR 4



T-Walk T4

TSR 5

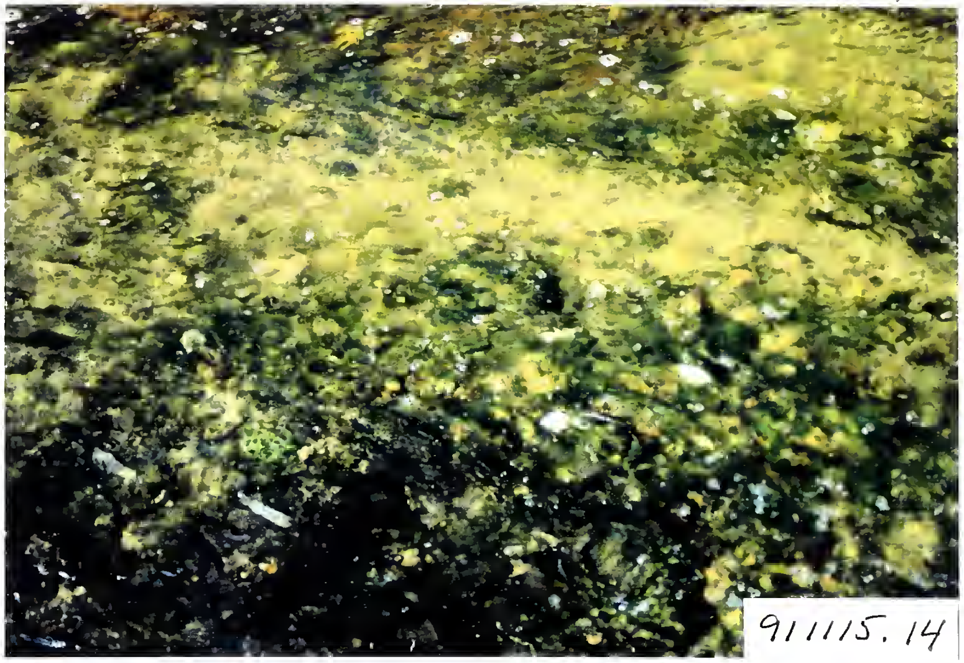
T-Walk T5

T5R 6

T-Walk T6

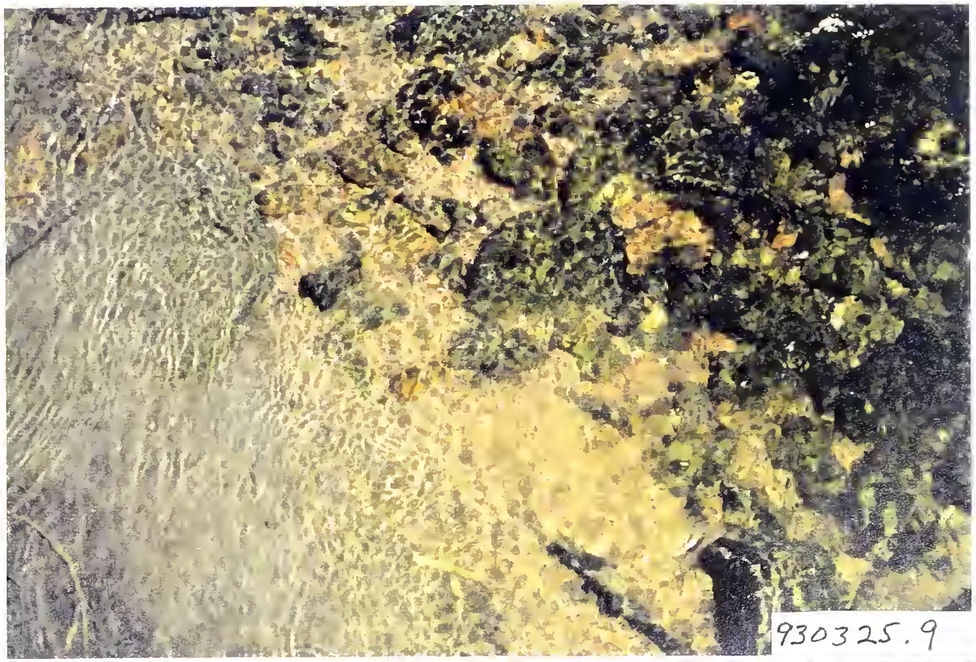
TSR 7

910515.28



911115.14

911115.12



930325.9

T-Walk T7

T-Walk T8

T-Walk T9